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ABSTRACT

The phenomenon of technological development has assumed great importance in the contemporary world. It is reflected in unprecedented growth in productivity with accompanying labor saving, in improvement of quality of products, in the launching of new products and services, and in the development of new branches of activity. This document reports on a research project carried out in Algeria, the Cameroon, France, the former German Democratic Republic, Indonesia, and the Republic of Korea. National teams from each country assisted in the endeavor. This report is divided into three parts. The first elaborates on technological development, internationalization, the need for technological development, and the dilemma of educational planners in developing countries. The second part details the International Institute for Educational Planning (IIEP) research programme and gives a summary of the major findings. Sections include the evolution of technological policies, impact on employment and qualification structures, the response of the formal education system, the state of government-education-industry relationships, and major implications for educational policy-making and planning. The final section details a summary of the respective case study for each of the six participating countries. Each summary provides the objectives , research methodology, and findings of the study. (Contains 16 references.) (RR)

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IIEP Research Report No. 85

Technological development and its implications for educational planning

by Bikas C. Sanyal

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International Institute for Educational Planning

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Technological development and its implications for educational planning

Bikas C. Sanyal

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This research project was carried out in six countries : Algeria, the Cameroon, France, the former German Democratic Republic, Indonesia and the Republic of Korea, in each of which it was necessary to set up national teams who approached not only schools, technical institutions, universities and private technical courses but also private and state industries. From this, the reader may well imagine the amount of co-operation which was extended to the responsible research staff in the International Institute for Educational Planning (IIEP).

Therefore, after having completed the task of summarising the findings, I would like to acknowledge the extensive efforts made by my research colleagues in the above countries (details of the institutions and names are given in the relevant case study summaries). Their enthusiasm and interest in such a new field of educational planning was a constant source of support and reassurance. This book represents a summary of all our endeavours and happily we know that it has already been useful in clarifying and planning the further development of certain areas of technological education.

I would finally like to express my particular thanks to Ms J. Collins, Senior Clerk, IIEP, who contributed to the different stages of the research and also in the preparation of the report.

Bikas C. Sanyal

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A. The phenomenon of technological development

1. Introduction

Webster's dictionary defines "technology" as the science of the application of knowledge to practical purposes. Technological development is therefore the progress that is made in this application. Related to the socio-economic context, technological development would mean progress in the application of knowledge to improve upon conditions in the economy and society.

As countries move from being agricultural to industrial economies and then on to post-industrial information societies, their characteristics change in many ways, including the role demanded of education and the employment of the work force. This evolution has been traced comparing the characteristics of the information society with those of industrial and agricultural societies as shown in Table 1.

Table 1. Major characteristics of the different societies

	Agricultural Society	Industrial Society	Information Society
Importance of research	minor 0.3% GNP or less	strong 1-2% GNP	very strong 2-3% GNP
Importance of formal education	minor 1% GNP or less	strong 2-4% GNP	very strong 6-8% GNP
Importance of communications	unknown	3-5% GNP	about 10% GNP
Proportion of work force			
in agriculture	up to 40%	10-20%	10% or less
in industry	15-25%	40% or more	20% or less
in information	12%	15-20%	50% or more
Use of time			
life expectancy	36 years	60-70 years	70 years plus
free time	3 years	12 years	19 years
on transport	1.8 years	4-6 years	diminishing
Level of urbanization	up to 25%	70%	diminishing
Role of mass media	minor	strong	enormous
Level of organization	simple	complex	extr. complex
Degree of interdependence among different agencies	weak	strong	very strong
Population growth	high	low	very low

Source: Luigi Dadda: The diversification of higher education. A view from technology and industry. In: higher education in Europe vol. X III, Nos. 1-2, 1988, p.54.

The Table shows that development of science and technology has resulted in increased importance of research and education, increased complexity of organisations, greater importance of communication, more of the work force in information, a major role for the mass media, and to a greater degree of interdependence, while on the individual level, there will be longer life expectancy and more free time and a decrease in time spent on transport, a lower population growth and level of urbanization (after an increase in industrial society).

With the advancement of biotechnology, food shortages can be eliminated and health facilities improved. It is believed that improvement of the environment will also be made possible by rational application of biotechniques. Progress in material science in the industrialised countries is not only leading to automation and restructuring of the employment pattern, work style and types of jobs through the use of "micro chips", but is also believed to bring about economies in consumption of energy, reduction of environmental hazards and change in the life style of people.

It has been observed that there has been growth of jobs in the service sector and a decline in manufacturing jobs in almost all industrialised countries except for Japan. The differences in the types of jobs in the two sectors and their different patterns of evolution have implications for education and training.

An interesting feature of technological development in the industrialised countries is that demand for goods and services has become more education-intensive in terms of production inputs, although there has been an increase in low level service workers such as waiters, sales workers and janitors. The exports of the industrialised countries tend to be more education-intensive than their imports. But due to the development of information technology, technology transfer enables an increasing shift of formerly education-intensive production of goods and services to the developing countries. New technologies are contributing to the internationalisation of the means of production and the implications of this for educational planning become very difficult to assess in a rapidly changing situation[1].

Changes in technology in the industrialised countries have had an impact on the relative productivity of different types of labour, since some applications of technology require better educated workers, where technology is embodied in forms of capital that complement education, or less educated workers where technology can be used as a substitute for education, e.g. computers have reduced the educational requirements of analysts by carrying out the measurement, manipulation and analysis tasks previously done by human beings. In some cases, technological development has led to more worker participation in decision making by

1. Levin, H. and Rumberger, R.: "Education, Work and Employment: present issues and future challenges in developed countries", IIEP, Paris, 1988.

releasing workers from repetitive routine work (which is done by computers) for such tasks as deciding on product quality, production-scheduling and assessing production needs -- tasks which need numeracy, literacy, reasoning, communication and problem-solving skills, calling for ever higher levels of education among workers. Thus, it has been argued, as time passed economies will need higher levels of skills in certain areas, while forces like technological development leading to automation may help lower skill requirements in other areas. This leads one to believe that technological development is not likely (significantly) to change the average level of skills required in the employment market of the industrialised countries in the near future. However, new technologies and new forms of work organisation will require new types of skills such as communication and reasoning. In the information society, an increasing number of workers are needed to create, process and distribute information. New occupations are created, and some old occupations will disappear or be transformed. One estimate is that in the early nineties, 50 per cent of the work force in industrialised countries will be working directly or indirectly in the information business.

Factor costs of goods and services are also undergoing significant changes. It is estimated that the manufacturing costs of semiconductor chips are about 70 per cent knowledge (i.e. research, development and testing) and only 12 per cent labour. In some pharmaceutical products, labour costs account for only 15 per cent and knowledge costs 50 per cent.[2] Another study reveals that 15 per cent of overall productivity growth in American and Japanese industry comes from changes in the use of labour, 25 per cent from capital investment, but no less than 60 per cent from technological change[3].

Such developments will lead to rapid obsolescence of skills, requiring the retraining of workers from time to time. These are the trends which have been noted in industrialised countries.

2. Drucker, Peter, "The changed world economy". In: *Foreign Affairs*, Spring 1986, pp.768-791.

3. Dennison, John, "Technology, higher education and the economy: A critical relationship". In : *Higher Education in Europe*, Vol. XIII, Nos. 1-2, 1988.

At independence, the developing countries had to expand their educational systems, since developmental efforts and departure of expatriates holding high-level decision-making positions created a heavy demand for education in quantitative terms.

As to development strategies, industrial development was generally favoured over agricultural, because planners and politicians thought that only dynamic industrial growth could create a modern state and lead the economy to "take-off". It was also believed that this would provide the basis for sustained economic growth, increase consumption and improve the overall economic condition of the people.

The production and consumption model imitating the industrialised countries was introduced in these countries which had very different forms of income distribution, factor costs of production, size of internal markets, basic needs and scientific and technological capability. Structural heterogeneity of the economy was increased through the import of capital and knowledge intensive technologies in a few modern and powerful enterprises, and in many cases, development of local technological capability has been based on the needs of these large enterprises. Insufficient local demand for technological competence has tended to impede growth of national skills. At the same time, the modern sector, expanding under the above circumstances very slowly and unevenly in these countries, has many of the same characteristics as that of industrialised countries, but with the addition of a number of specific problems (as demonstrated by the case studies in this research).

2. Technological development and internationalization

The spread of international trade and investment is producing a very high degree of economic integration both among industrialized countries, and between them and the developing countries. It is against this background that a new international division of labour is emerging, in which the developed economies are not only reliant on Third World resources of energy and minerals but also on labour. This international division of labour, in addition to what has been said above, is also generating a limited amount of industrialization in the developing countries.

Although technological knowledge of the highly trained manpower is essential for technology transfer machinery and scientific equipment are important vehicles for the creation and dissemination of technology. The internationalization of their production is thus a mechanism for the dissemination of technology. However the spread or depth of penetration of new technology differs according to whether the machinery is intended for the manufacture of consumer, intermediate or capital goods.

Machinery that is specifically designed for a given activity, industry or group of activities is distinct from multi-purpose machinery which can be used both to produce the first category and to reproduce itself. While all types of capital goods are vehicles for technological change, multi-purpose machinery occupies a strategic position in the generation and dissemination of technology. Such machines govern the capacity to design and produce new machinery incorporating innovations for all the different sectors of the economy. The production of this type of capital good is henceforth dependent on the world market for machinery because it requires the import of some types of machinery and the export of others. The type of machinery in which a country tends to specialise within the framework of the international division of labour therefore determines the country's position in the production of technology at world level, i.e. the production of knowledge directly related to the design of machinery is increasingly located in accordance with each country's specialisation in the different types of machinery. This is so, for example, for research and development (R and D) in mechanical engineering, chemicals, electronics and transport. On the other hand, atomic and space research is more directly associated with the arms sector and is conditioned rather by each country's position in the world military system. This situation evidently has consequences for the nature of the qualifications required and for the corresponding structure of training. The qualifications and skills required for the design of equipment and generation of knowledge are of a higher level than those required merely for the manufacturing process. The internationalization of technological production is therefore likely to have a considerable impact on the training systems of different countries.

3. The need for technological development, particularly as regards developing countries

The institutionalization of wage-bargaining based on relatively full employment, and the increased competition of international trade are powerful stimuli to technological change in the developed economies. However, the creation and dissemination of techniques are mainly dependent on public research funding, and more generally on the organization of technology transfers by the state, especially between the military sector and the civilian economy.

Studies show that whenever an innovation occurs, inter-country and intra-country disparities increase,[4] at least in the short run. The benefits that accrue from innovation increase the wealth of those who are already rich. Thus the technological development that is taking place in developed countries tends to contribute to the widening of disparities in development. Unless local technological capabilities are developed on a world-wide basis, disparities will increase further.

The developing countries have an overriding need to expand their agricultural and industrial outputs and their basic services. These needs can only be met by rational technological changes achieved through the acquisition of the required knowledge through technology co-operation and the transfer of know-how from industrialised countries and its application for exploration, exploitation, management, distribution and conservation of the natural resources they possess[5]. Consequently, developing countries have to be more conscious of the need to master technological change, at least in some strategic fields. It is being realized that technological dependence leads to economic dependence which, in its turn, affects political sovereignty.

In order to be able to adapt a technology to local needs, it is necessary to master that technology: otherwise there will be serious losses of investments made in imported technologies just because that technology did not suit the local climate, conditions, and peculiarities of natural resources and culture of the people. Another reason for

4. For example see Skorov, G.E., ed. (1978), *Science, technology and economic growth in developing countries*, Oxford, Pergamon Press.

5. OECD: "New technologies in the 1990s: A socio-economy strategy", OECD, Paris, 1988, pp. 22.

developing local technological capability is related to the serious unemployment problem facing developing countries in recent times. While imported machinery can be highly productive, it also reduces employment of human resources which in developing countries are normally available in abundance.

Finally, it is believed that the harmonization of education and employment can be improved by linking the education system with the productive sector. This calls not only for flexibility of the educational system to meet the needs of the productive sector but a willingness of the productive sector to make the best use of the output of an increasingly complex and diverse educational system. Technological development provides a way to achieve this[6]. However, the task of educational planners becomes more complex if a response is to be made to needs for technological development, especially in the context of internationalization of technology.

4. Internationalization of technology and the dilemma of educational planners in developing countries

The professional, technical and related workers, the managerial and administrative staff and the production and related workers who run the economic machinery of a country are the product of the education and training system. Technological change, whether local or external in origin, however entails new methods of production, calling for new types of skills. This necessarily alters the structure of education and training. Unfortunately, in many countries even when educational planning is regarded as a major instrument for economic development, it is rarely considered explicitly with reference to technological change. Conversely, technological development policies as formulated and applied seldom involve educational planning. However, evidence of an increasing gap between skills in demand and skills in supply suggests that an analysis of probable trends in technological change is becoming crucial to planning human-resources.

6. OECD, op.cit. p. 23

The failure to give due consideration to technological changes is probably one of the chief shortcomings of educational planning. One of the penalties of this planning deficiency is the mismatch between education and employment: shortages of certain types of skills and surplus of others.

From this point of view, traditional methods of manpower planning need to be revised. Certain methods in use assume that labour productivity is constant over a given time-span and consequently, any possibility of technological change is ruled out. Other methods explicitly envisage technological development, but equate it with a simple rise in labour productivity, represented by a coefficient of manpower needs. This ignores the impact of changes in techniques on the nature of jobs and skills. All these methods of manpower planning fail to integrate technological development and *a fortiori*, all the constraints that a technical change generated from outside entails for education in the developing countries. If educational objectives cannot be defined independently of technological change, and if the latter is mainly of external origin, as in the case of most developing countries, then educational planning has perforce to be geared to the external forces.

In the developing countries, the constraints imposed by the internationalization of technology are still more severe, inasmuch as these countries are weak in the production of machinery and of technical and scientific knowledge. Industrial development in most developing countries is confined to consumer goods and intermediate goods, and is based exclusively on technologies imported from the developed countries. This creates particular needs as regards skills. The repeated importation of increasingly specialized machinery and knowledge may entail the acquisition of more and more compartmentalized skills. These skills are increasingly restricted to the utilization of imported machinery, and may not lead to their being used for local development, if deliberate efforts are not made in this direction. The internationalization of technological production also tends to make the structure of skills more and more rigid, by imposing uniform technical standards on the world market.

Changes in the conditions of the worldwide production of techniques affects the goals of educational planning in the developing countries. By unifying techniques on a world scale and by narrowing down the possibilities of choosing between them, it imposes a limited and rigid range of qualifications on educational planners.

As a result of increasing specialization in the production of machines, knowledge and skills, the application of techniques too is becoming increasingly complex. This is where the role of engineering to integrate compartmentalized areas of knowledge and to combine them with machines and skills becomes important. The development of engineering exports by multinationals may be perceived as a means of maintaining and reinforcing developing countries' technological dependence, since in part it extends to the diffusion of techniques the power of control already exercised by the large firms of industrialized countries over their production.

This can sometimes create obstacles to direct access by the developing countries to the world technology market, thereby making more difficult the definition of the aims of educational planning. In some extreme cases, control by external decision-making centres over the selection and implementation of imported techniques can effectively prevent planners from themselves formulating the training needs entailed by the imported technology.

In these circumstances, any educational planning becomes highly complex, since it is no longer possible to define training objectives. In extreme cases, it is left to the foreign firms themselves to train the managers, technicians and skilled workers (regardless of level of skill) called upon to operate the plants these firms have built. This happens with "turn-key" contracts, in which the national operator buys a factory complete with its full operating labour force. It also happens with international training contracts.

From the above discussion, it is clear that if educational planning is to be oriented towards making countries capable of deciding their own destiny, development of local technological capability should become an explicit objective. This calls for articulation of the desiderata of technological development. First among them is the capacity to remain abreast of the state of technological progress around the world. The second is the capability to choose the type of technology which will make the optimum contribution to the long term development of the

country. The choice of techniques needs not only technological capability but also negotiating skills to decide on the terms of import. Even if import is of the "turn-key" type, the proper management techniques must be available for developing the skills needed. The third is the capability of assembling the different components of a machine. This has generally two stages: semi-knocked down (SKD) assembly where not all components are disintegrated and thus needing less sophisticated skills, and complete knocked down (CKD) assembly where all the parts are disintegrated. The third capability in order of sequence is to depackage the technology which would help national firms to get thoroughly acquainted with the different parts so as to adapt some of them to local needs. At this stage the details of the theory of material properties and manufacturing knowledge are needed. This leads to the fourth capability of designing products suitable for the country's own working pattern and needs. The last step which will follow design, is the self production of the equipment or machinery. Moving from one capability to another brings changes in educational needs and increasing sophistication. But at one particular point of time, all these capabilities may be needed simultaneously for different components of the same machine or the different products of the same firm.

However, it should be remembered that control over the organization of production and technologies depends not only on the technical capabilities of the workforce, but also, and to a large extent, on the forms and levels of organization adopted, and on how production is managed. In that case, control over the machinery of production also demands capacities pertaining to the organization and management of companies and production facilities. In many countries, this organizational and managerial capability is sadly lacking, which thereby worsens the problems relating to control over technology alone. The implications of this for educational planning are obvious.

It should also be understood that the process whereby the above skills are selected and adapted to local conditions calls for a system to produce new knowledge, however partial. This leads us to the identification of research skills essential for local control over the process of technological change. If a country plans to substitute the imported knowledge needed in the production process by local knowledge, research skills are central to the overall process of selection, acquisition, control, adaptation and replacement of imported

technologies by national technologies and imported products by new products. Development of human resources to perform this task of research is, therefore, a major responsibility of the education system. The above provides the global background to the IIEP research project one further comment needs to be made. It is obvious that the education system cannot focus solely on technological and economic development. Although the present research concentrates on the issues of technological development and its implications for education, and on delineating the specific tasks and programmes of education, the broader goals of education -- social, cultural and non-economic, have to be kept in mind. Education also has a role to play in informing the population of the harmful effects of technological progress, for example health hazards and dehumanizing effects and can assist the population in save guarding themselves. With these provisos in mind, the objectives of the present research were elaborated and are outlined in Part II together with a summary and findings.

B. The IIEP research programme and a summary of the major findings

During its 1984-89 Medium Term Plan, the IIEP set out to address the problem of scientific and technological development and its implications for educational planning. The hypothesis was that in developing countries, educational planning hardly ever takes into consideration the conditions of technological change, while at the same time it is evident that the relationship is extremely important for development.

The projects under this programme covered a wide range of countries from those that have pursued a national policy of technological development (German Democratic Republic, Republic of Korea), others who have applied partial policies of technological development (France, Indonesia), to yet others whose policies were based essentially on imported technologies (Algeria, Cameroon). The countries were selected on the basis of the interest of the national researchers to participate in the research programme and the availability of data related to the different issues. The consequences in terms of manpower needing to be trained to use, maintain or design new products and processes differ greatly from one country to another.

Although these research studies did not themselves attempt an economic and social analysis of technological policies, they had of necessity to take them into account, but they were chiefly concerned with investigating the relations between the various scientific and technological development policies on the one hand, and the content of educational policies and educational planning processes, methods and techniques on the other. The resulting conceptual, methodological and technical effort would ultimately be a source of enrichment to the Institute's training activities. The aim of these studies and analyses was to examine the links between various policies and decisions relating to the processes of technical change and ongoing educational policy and practice, in order to identify the role ascribed to educational planning, and to draw conclusions with a view to improving its relevance and effectiveness. The impact of scientific and technological development on the overall development strategies of developing countries has been the subject of another recent Unesco report[7].

In giving consideration to the diversity of scientific and technological policies and the diversity of the economic structures into which they have to fit, the present research aimed at revealing, by using existing work and results where possible, the processes by which the different qualifications or skills necessary for the implementation of these different technological policies were produced. In particular, attention was paid to the criteria that govern the choice of different programmes and streams, and to their articulation, notably between science and technology teaching, technical teaching and vocational training, as well as the linkages between training and production, and between higher education, applied research and fundamental research. It goes without saying that these research studies necessarily took into account the distribution of institutional responsibilities for education and training, not only between the public and private sectors, but also between the different ministries and governmental agencies. The studies, however, were restricted to the formal sector of the economy although in the developing countries the importance of the informal sector and the

7. International Council for Science Policy Studies: Science and Technology in Developing countries; Strategies for the 90s: A report to Unesco, Unesco, Paris, 1990.

need for upgrading the skills of workers in this sector are high. An attempt has been made to handle this issue in a recent ILO publication[8].

While our research studies were by nature concerned to describe things as they are, their ultimate aim was to stimulate thinking as to the conditions under which education and educational planning might play an active part in creating the conditions for dynamic technological policies designed to foster local control, whenever this is in line with national aspirations and resources, over technical choices, adaptations and innovations. For this, information concerning the results of past educational policies was required, expressed in terms of numbers of people trained at different levels and in different types of education and training, with a view to finding out whether education, by its nature and its "outputs", provides the necessary paths towards scientific and technological development, on the one hand, and whether it was capable of meeting the demands of scientific and technological development policies, on the other. Similarly, these research studies should lead to a better understanding of the criteria governing the allocation of resources in order to meet the simultaneous demands of basic education and education for scientific and technological development, as well as the development of new instruments for measuring the relations between education and employment and improving vocational and technical educational planning methods at all levels. These studies will, it is hoped, enable the Institute to play a more active part in the current debate on the social responsibilities of education and to equip it with the means to update its training activities, focusing on one of the fundamental aspects of fruitful articulation between education and development.

The studies therefore followed different directions depending on the priority problems of educational planning in the country concerned and the sector of industry studied. For example, in the Cameroon and Algeria, the oil industry was selected, and in the Republic of Korea and Indonesia, the electronics industry was the focus of study. In developed countries, the global role of higher education in the country's scientific and technological development (with special reference to the computer industry) was studied in the German Democratic Republic while the

8. Fluitman, Fred (ed.): *Training for work in the informal sector*. ILO, Geneva, 1989.

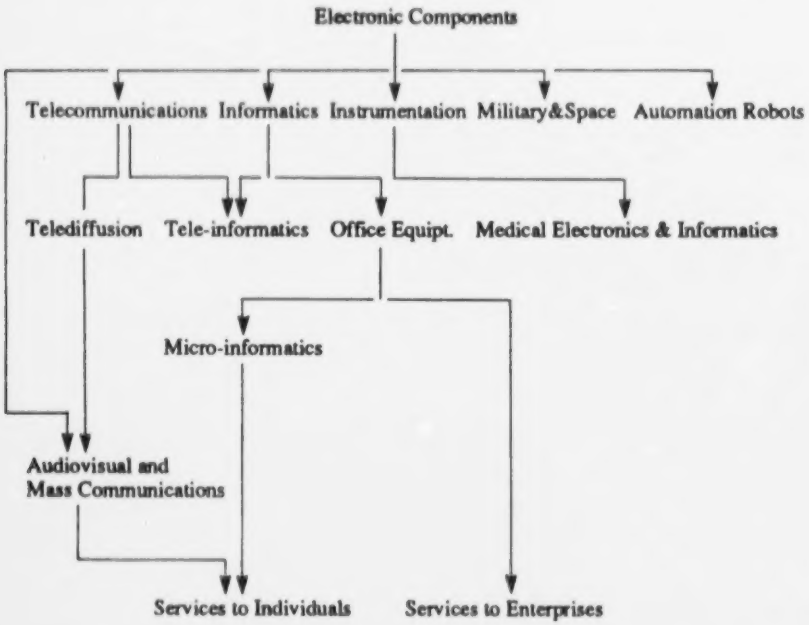
French research examined the establishment of co-operation between higher education, research and industry in the high technology sector within a particular structure, the "technopole".

Resumés of the individual findings of the studies are given in Part III of the report together with the objectives and methodologies used in each case and the policy implications derived. This section, Part II, is devoted to synthesising the various elements which came under study i.e. -- the evaluation of technological and industrial policies and mechanisms used to implement them, their impact on employment and qualification structures and the response of the educational system to these developments. It was hypothesized that the state of government-education-industry relationships would be of critical importance to the success of technological development and these were examined in some detail to afford opportunity for comparison on an international basis and to derive some of the major implications for educational planning.

1. The evolution of technological policies

As noted in the French study, the primary objective of any technological or industrial policy is that it should be operational in terms of development. Thus any such policy should be global, and constant in application over the long term. Global because the development of industrial or other sectors depends on each element keeping abreast of new knowledge. This is illustrated by the composition of the electronics industry (Figure 1). Constant, because investment in new technology involves high risk and the need to plan with a degree of confidence for some years ahead.

Figure 1. Interdependence of the electronics industry[9]



The case studies undertaken in this research emphasise the importance of globality and constancy and the disadvantages to both industrial and educational development and planning where one or both are lacking. On a scale of emphasis placed by the government on these two factors while ignoring their actual technological status the countries may be placed as follows (Figure 2):

9. C. Stofaes, Politique industrielle, Institut d'Etudes Politiques de Paris, les cours de droit, Paris, 1984, p. 456.

Figure 2. Extent of constancy and globality of technological policy and characteristics of implementation

High					Low
German Democratic Republic	Repub.of Korea	France	Indonesia	Algeria	Cameroon
1. mid 1960s	1.1969		1.1983	1.1976	1.late 1986
2. mid 1960s	2.1969	2.only	2.	2.	9.
3. mid 1960s	3.1969	4.for	4.for	4.	10.
4. mid 1960s	5.1969	5.certain	5.state		
5. mid 1960s	6.1981	7.sectors	7.sector		
7. mid 1960s	7.1981	8.(mainly	8.only	9.	
8. mid 1960s	8.1981	9.state)	9.	10.	
9. mid 1960s	9.1969	11.	11.	11.	
11. mid 1960s	10.1969				
	11.1969				

Characteristics of Implementation:

1. Master Plan for Technological Development
2. Sectoral Plans for development and relevant Ministry established
3. Coordinated educational planning
4. State resources for R&D and specialised research institute
5. State resources for training and training centres
6. Tax exemption for R&D investment
7. Collaboration of state educational institutions and industry in research
8. Collaboration of state educational institutions and industry in training
9. Government long term procurement policy
10. Favourable policy on technological imports
11. Protected industry status

Such policies may in fact be forced upon a country seeking to ensure its future development and they can only be implemented by careful global planning. This was the case for the *German Democratic Republic* when in 1966 its Council of Ministers met to discuss basic problems of economic strategy. Given the relative lack of national resources and scarcity even of human resources, the country had to embark on a programme of energy saving economic growth. Information technology reduces requirements for other resources and it

was accepted that the application of micro-electronics and computers was essential to ensure industrial development. There is also the fact that the country is isolated from the main centres of innovation in electronics: flow of information and import of technology are impeded. Thus a major concerted effort was essential to develop its own industry, which though behind those of the most advanced countries, nevertheless has contributed, as planned, to resource and energy saving.

The College of Technology, Dresden, became the centre of excellence in electronic calculating technology and at the same time training programmes in rudimentary informatics were introduced in university courses for mathematicians, engineers, scientists and economists. The basic strategy for education followed the development of electronics at each stage. A well-defined national policy on technological development is accompanied by active state intervention to provide the relevant resources which may come from education, industry, regional or government sources. Since all are involved in the micro to macro planning process, participation and co-operation are secured. At present, this sector is planning the introduction of fourth generation computers by 1990, as targeted by the Party Congress, together with the setting up of certain quantities of CAD/CAM stations, and provision of micro, mini and macro computers[10].

The position of the *Republic of Korea* was essentially much the same as for the German Democratic Republic. Without many natural resources but rich in untrained but literate human resources, this country too recognised the opportunities for development in high technology. Unlike the German Democratic Republic it lacked skilled manpower and an experienced planning system, but was, on the other hand, open to foreign investment and expertise. In the beginning it was totally dependent on imported technology and had a low rate of R&D activity. More than 90 per cent of its exports are made by local subsidiaries of foreign multinationals while nearly all domestic demand is met by local firms. Under pressure from these foreign firms, the Government which previously adopted a protection of strategic infant industry policy has had to liberalise trade policies and allow free computer imports. The

10. Recent political changes in the country will, no doubt, have effects on the development of technological policies with consequences for education. It is too early for the present report to consider them.

country built up its protected industry, with the aid of foreign expertise, at the same time emphasising science and technology in education, creating a Ministry of Science and Technology (1967), enacting a series of laws to promote development (1969 Electronics Industrial Promotion Law and 8-year Development Plan for the Electronics Industry (1969-76)) and establishing institutions for science and technology around the country.

However, at the beginning of the 1980s the Government had to face the fact that technological superiority was the key to future development. The high cost of imported technology means that local research capability must increase in the future. Policies began to change rapidly in the 1980s -- the 1981 Industry Promotion Law established an Electronics Support Fund to be financed by public and private contributions and tax incentives for R&D were allowed in the form of setting aside a certain percentage of profits. The Korean Institute for Electronics Technology had always been given a comfortable budget and adequate manpower but as the new Korean Electronics and Telecommunications Research Institute, it is now responsible for a master plan for VLSI and computer development. Private enterprise and state research institutions collaborate on R&D supported by a government procurement policy. However, such policies have not been entirely successful globally, i.e. design suffers from lack of high level R&D staff, equipment and related software. Small and medium size firms cannot obtain loans easily or undertake major R&D without a mechanism to co-operate, share costs and reduce duplication of efforts.

Policy in *France* has many of the characteristics of those enacted in Korea but only as regards the strategic telecommunications, military and space sectors which are now well developed and competitive internationally. The views of the authors were that the role of the government has been the determining factor in the development of the electronics industry in France, and recognition of the strategic character of the industry has been late in arriving or at least late in being constantly applied. The Gaullist Government did devise a master plan for the industry 1967-71 which created state firms for computers (successful), peripherals and components (less successful). However later governments merged policies into overall industrial strategy, reducing

the emphasis on the electronics industry. As a result, policies have been fragmented, inconstant and delayed (for informatics, integrated circuits) or non-existent (for office equipment and industrial components).

Certain echoes of the French experience are to be found in *Indonesia*. The telecommunications industry, with government support and protection, has expanded and adopted the latest technologies while the private sector, subjected to strict import controls, has languished at the complete knock-down stage. While the large state enterprises have made investments in R&D, and co-operated with the National Research Institute to produce a significant number of new products as scheduled under Five Year Plans, the private sector has a low level of R&D activity. This, despite the fact that in 1983 electronics was one of the industries designated to be promoted by the Board of Strategic Industries. The Government has recently liberalised import controls and set up (1987) an Inter-university Centre for Electronics to pool resources for the coordinated development of the industry. The segmentation of the industry into modern coordinated state and backward isolated private sectors is extreme, the latter not yet having co-operated amongst themselves due to problems of competition and trade secrecy. At the same time, state enterprises complain of lack of local technological capability.

Turning now to the two countries where the oil sector was studied, one (Algeria) has very much more experience and a more developed infrastructure than the other (Cameroon). However, as with the Republic of Korea and Indonesia in electronics, both were preoccupied in their policy making as to how best to import the necessary high technology and expertise, keep control of the industry and eventually by intensive education and training, be in a position to manage and develop the sector themselves.

The *Algerian* National Charter 1976 spelt out the long term policy of independent development and creation of a technological base. Petroleum was to be the motor of economic development which would fuel production of pesticides and fertilisers to modernise agriculture and of plastic materials for irrigation, packing, etc. Algeria earns most of its revenue by oil exports (in 1987 hydrocarbons produced 96 per cent of revenues) and its Ministry of Energy is a very powerful one. The country has immense resources of crude and hence no uncertainty about investing for the future. Thus in the 1960s and 1970s large sums were

spent: national companies were created e.g. the National Company for Petrol Engineering and a National Plan for Science and Technological Research was drawn up to cover 1974-77, the National Institute of Hydrocarbons and Chemistry and the Algerian Institute of Petrochemicals were established.

From 1962-76, this sector was the greatest consumer of foreign technology, taking 48 per cent of all contracts with foreign firms for transfer of technology. The diversity of foreign partners (about ten multinationals in all) reflected anxiety to reduce dependence on France, to promote competition as regards price, delivery and financing and to get the best available technology. At first turnkey contracts were arranged but following unhappy experiences of production and maintenance breakdowns, "product in hand" contracts were adopted under which the foreign company had to make its accumulated know-how available plus experts and documentation, and undertake to train Algerians in the quantities and conditions agreed upon, so that by planned phases, the companies would eventually be Algerianised (in the period 1974-78 there were only 2000 engineers in the industry of whom two-thirds were expatriates).

At present production of the industry is divided 50/50 into public and private sectors, the public sector comprising one massive complex plus several other satellites, while the private sector is composed of small firms engaged in areas where the technology is simple and easily mastered (i.e. once again the phenomenon as noted in Indonesia of a modern state sector and relatively backward private). However, even in the state sector there has been a lack of clear policy for the accumulation of expertise and no national team as yet exists which would be capable of taking over one of the existing units.

Thus the sectoral policy followed has not been entirely coherent although covering the areas of industrial planning, training and research. Needless to say it has not involved the educational system in any way.

The *Cameroon* too recognised from the date of independence that its development would have to rely on foreign expertise while encouraging Cameroonisation (for the latter as from the Third Plan in the 1970s, it created financial and technical structures to assist local small and medium size enterprises).

Efforts to plan transfer of technology have only recently appeared on the agenda, the National Committee for the Transfer of Technology has as yet accomplished little and the Technological and Industrial Research Institute is still awaited. Technological policy in the oil sector concentrated on the practical aspects of setting up and training manpower for the refinery, which was highly successful.

Experience in this country of development of the modern sector is very short, e.g. the oil industry began operations in 1980 and it is only at the end of the 1980s that a Master Plan for Industrialisation is being drawn up in which the strategic industries (oil, plastics, gas, among them) appear. The plan still assumes a strong dependence on foreign technology and only general statements are made on the provision of technical education.

Evidently policy making depends on the availability of both capacity to plan and the basic data, which are not generally found in abundance in developing countries. However, it can be seen that recently Cameroon and Indonesia have recognised the importance of a master plan, an organisational structure, interdependence..... The French study attempted to list some of the elements necessary to make the policy operational. Combining these with the experience of other countries participating in the research, we find that development of an industry is encouraged by:

- A long term perspective (master plan, state procurement policy) to encourage enterprises to take risks in innovation;
- Centres of excellence/research to master, accumulate and disseminate knowledge;
- Development of a mechanism for risk capital and investment in the sector;
- A mechanism to enable the different agencies/actors to communicate and co-operate with each other;
- An overall view, so as not to neglect certain sectors -- public/private, consumers, component suppliers, formal and non-formal education and training.

2. Impact on employment and qualification structures

While it is evident that the growth of new industries like telecommunications, electronics, oil exploitation and refining, will radically change industrial structure and demand the education and training of a large corps of skilled workers in any country, the impact on developing countries will be more extreme given the existing generally low level of activity of the secondary sector and relatively low proportions of skilled employees.

The most striking case amongst the studies carried out was that of the *Republic of Korea*. Here the economically active population was 10m in 1970 rising to 15m in 1974 with a 96 per cent employment rate. During the period, employment in the primary sector fell continually (from 63 per cent in 1960 to 30 per cent in 1983) while manufacturing rose from 9 to 23 per cent. The electrical and electronics sector made a significant contribution to this increase, employment rising from 181,000 in 1976 to 204,300 in 1982. Nationally, the qualification structure is increasing in quality; in 1982 4.6 per cent of the work force were engineers as against 3 per cent in 1976, the proportion of technicians remained the same at 27-28 per cent, clerical staff increased from 11.5 to 20 per cent and craftsmen fell from 58 to 48 per cent.

In Korea, the manufacture of electrical and electronics goods is still concentrated in large firms where there is scope to take advantage of automation. In this industry the qualification structure demonstrates the impact of automation, for while the proportion of engineers rose to 6 per cent in 1982 from only 3 per cent in 1976, the percentage of technicians employed declined. The ratio of Engineers : Technicians : Craftsmen was 1 : 10 : 22 in 1976 whereas in 1982 it had changed to 1 : 4 : 11, i.e. in the pyramid of manpower structure, the top strata has greatly gained in importance and needs less middle level technician and lower level skilled to back it up. However, the survey conducted in electronics firms which covered the period 1981-85 showed an overall rise in function and educational attainment. The proportion of those classified as managers, professionals and technicians rose 4 per cent between 1980 and 1985 while B.Sc. or higher degree holders rose 2.6 per cent. More than half the sample of employees stated that their qualifications had to be higher now than in 1980 -- even 50 per cent of salesmen -- but more significantly 83 per cent of R&D staff replied that they needed higher

qualifications. The conclusion drawn from this was that the increasing quality of the labour force resulted from both demand for higher qualifications (real needs of the job) and from over-supply of certain graduates with a general education. It was found that enterprises who had expanded rapidly by introducing new technologies increased their proportion of graduates four times during 1980-85 and had high proportions engaged in R&D. Other companies who had experienced comparatively little innovation had only marginally changed their employment structure. Nevertheless they too had increased their proportion of graduate employees by 2-3 per cent. This trend to higher educational qualifications is forecast to continue: demand for engineers will increase by 18 per cent per annum while overall demand for manpower is estimated at only an increase of 6 per cent a year.

In this study, a particular enquiry was made as to the effects of automation. Only 18 per cent of the sample of enterprises indicated that automation had resulted in a surplus of employees which had been dealt with by retraining and transfer. Innovative firms seem to be highly elastic in their labour absorption capacity, though most have not yet reached the fullest extent of automation.

Forty-two per cent of the sample of firms had their own training facilities, the remainder sending their staff to other training centres, these being foreign companies. Those with their own training centres invited foreign staff to assist with the courses. In line with this finding, 40 per cent of the sample of employees had received in-company training and 33 per cent overseas training. Training offered by other companies, and educational and research institutes in Korea accounted for only 10 per cent of the sample. This retraining resulted in some upgrading of status in that 10 per cent of the sample had changed from technician's functions to those of engineers.

The higher qualifications of employees, while a necessity for the industry, have brought certain problems for personnel management, i.e. job mobility (as noted above). Education and training have made them more flexible and ambitious for upgrading. One example given was that of R&D personnel (in the wage scales they rank second to management); these staff are leaving to become lecturers in universities who are paid more and the electronics industry is suffering a brain drain of high level staff to teaching.

The picture given of the telecommunications/electronics industry in *Indonesia* tells a somewhat similar story in several respects. Employment in state enterprises grew 2.7 times between 1980-85 while the work force in the private sector doubled. The survey showed that all types of staff needed higher qualifications in 1985 than in 1980. Sixteen per cent of those employed in state enterprises were graduates in 1985 as against 6 per cent in 1980. The proportions of professionals, technicians and sales staff increased while those of clerical and skilled production workers declined. The private firms experienced no increase in qualifications but employed less sales and clerical than formerly. The firms reported that the introduction of new products or processes had generally not caused redundancies but shortages, particularly of R&D and design staff, in the manufacturing and service firms.

Fifty-six per cent of the employees surveyed had received pre- and in-service training and 14 per cent had undertaken to continue their formal education (to 1st degree standard) while working. There was a high rate of job mobility: 40 per cent had changed their job during the five years 1980-85, 12 per cent of them 2-3 times. The reasons given were career prospects and additional professional competence. Data on functions of the sample of employees showed that such job changes resulted in an increase of R&D/design staff and a decrease in the numbers of maintenance personnel. Salaries in real terms increased on average 40 per cent in the five-year period.

Problems reported were, as stated above, the shortage of R&D and design staff: enterprises are obliged both to send trainees abroad and recruit foreign staff -- two-thirds of the firms employed foreign staff in high level posts. The problem is aggravated by the hijacking of bright graduates trained in one firm by another and the creaming off of the best graduates of state universities by the universities themselves and by the state enterprises -- causing the private sector to rely on the output of private non-officially recognised universities where courses and research are biassed towards the theoretical.

As with electronics, employees in the petrochemicals industry require a high level of qualifications and skills, and similarly enterprises are obliged to organise mass in-service training programmes. On independence, *Algeria* possessed little competence at all in hydrocarbons and thus the impact of the oil sector can clearly be seen from the fact that now this sector provides about 8 per cent of industrial employment.

Since 1972 it has expanded at an average rate of 10 per cent per annum. The impact can also be appreciated in that in the firms surveyed, the structure of employment shows an almost complete absence of non-qualified staff: the predominant function is technician (58 per cent), with 21 per cent professionals and 20 per cent skilled maintenance. Algerianisation in the sector is well under way: it varies by type of firm being 67 per cent in plastics and almost 100 per cent in fertilisers. Very few expatriates are to be found at lower levels. However, the production of high level technology staff has encountered some problems, it being found easier to replace foreigners in management and marketing than on the technical side. This is thought to be the result of several factors which will be revealed below.

There are two types of training available for staff in the oil industry -- sector and enterprise training. Sector training falls under the responsibility of the Ministry of Energy and in the 1960s the Algerian Institute of Petrol and National Institute of Hydrocarbons and Chemicals were established which remain the main agencies but were followed during 1964-78 by ten others responsible for such areas as mechanics, finances, etc. AIP covers gas, chemicals, petrochemicals, plastics (since 1973) and in 1984 offered a Ph.D course on polymer chemistry. AIP also offers refresher courses for engineers and technicians. It is also responsible for R&D, i.e. it is a specialised and large institute (half polytechnic/half university) having 1000 places for engineering and 1500 for technicians. It recruits many of its staff under co-operation agreements. The Institute has close links with the sector regarding the programmes and uses employees from industry as staff (as well as foreigners). In total it has trained over 10,000 people (60 per cent of them technicians). Thus the strategy of the sector has been not to use the formal education system to meet its needs. Despite the close links and specialised nature of education and training, this system has not escaped criticism -- the programmes have not kept up to date, the liaison committee does not function adequately, as a public bureaucracy, it is resistant to change; the trainees have not shown much tendency to innovate and the operator trainees do not always give good results.

Enterprise training has also been given to large numbers. It may be given on recruitment (for lower level posts), consolidation, and on promotion. Sonatrach, the largest state company, itself trained 1500 staff (50 per cent of its employees) during the period 1970-75. Most of them

were technician level, but there were also 63 management, 166 engineers and 80 accountants. Prior to 1970 most training by the company had been given abroad but by 1975, 95 per cent of it was done locally.

This sector/enterprise training system was established at a time when the universities in Algeria were still being developed. The advantages were the proximity of the courses, which were specific to needs and of a duration to suit the industry. The results can be seen in Algerianisation of the manpower but expatriates are still needed for maintenance and technology, i.e. there is still a problem of in-depth mastery of this high technology which is revealed by the fact that few innovations have been made and the same processes have been used for the past twenty years. One factor may be that the local market has to buy what is produced in the country, so there is no incentive to change. Secondly, within the salary structure in the industry, employees are better paid in production than on the technical support side so that the best stay in production. Professionals are not highly motivated since their salaries conform to all those in national enterprises creating a situation of stability-lethargy -- since the beginning of the 1980s there has been little staff turnover. In addition, technology is not considered a high status occupation in the country, though attitudes are slowly changing.

The direct impact of the oil sector on the employment structure in the *Cameroon* has been small (0.5 per cent of secondary sector employment in 1986). However, these jobs are highly significant for the country's technological development since practically all of them entail major and costly pre- and in-service training and the employees are amongst the skilled elite of the country.

The survey showed that employment in the enterprises had almost doubled between 1980-86 (to 3000 jobs). The percentage of expatriates employed had remained stable at 10 per cent -- the multinationals having higher proportions of 15-19 per cent as against the Cameroonian refinery's 9 per cent. The firms had increased the proportions of employees having Bac or higher qualifications by 6 to 10 per cent over the 5-year period. The problems raised were shortage of experienced engineers and computer operators and the quality of primary and secondary school leavers.

Data from the sample of employees clearly showed that the oil industry attracted first generation educated who have had to make their way independently -- half those who had higher secondary education had worked while studying and 37 per cent of graduates had worked to achieve higher education. In addition, 57 per cent of the sample had received in-service training (this concerned mainly skilled workers) while higher level staff were sent abroad. In 1980 41 per cent had classed themselves as professionals, 26 per cent as technicians, 16 per cent as skilled workers and 17 per cent as "other". The proportions in 1985 were 45 : 28 : 12 : 15, showing an increase in status during the period. Forty-five per cent of the sample had attained relatively high salaries in 1985 as against 18 per cent in 1986.

An important training resource in the country is that of the locally owned refinery which trains not only its own staff but those of other enterprises. While so far it has concentrated, with great success, on middle level manpower, it will with the expansion of the industry to gas and fertilisers, have to extend its activities. Its problem is how to cater to higher level training, particularly R&D, and it feels the time is ripe for a co-operative industry-higher education mechanism to develop its activities further.

Examining the experience in a developed country, the *German Democratic Republic*, which clearly acknowledged in its policy the strategic need for general technological and computer literacy to save scarce resources, we find similar rapid growth rates of the electrical and electronics industry. This sector was the fastest growing amongst industry, its index of production expanded 42 times between 1950 and 1985 and within the sector production of electronic components and numerical control devices has in recent years been the most rapid. The proportion of industrial workers in the electronics sector rose from 9.6 per cent in 1950 to 14.5 per cent in 1985.

Profound changes have taken place in occupational and qualification structures, coupled with a marked rise in educational standards. These were the result of long term educational planning based on a 10-year polytechnic school followed by a system of further education in vocational training schools, technical colleges or universities, as well as adult education courses run by enterprises. (The educational system will be dealt with in more detail in the next section, but it must be noted that even the 10-year polytechnic school children

receive some practical training in enterprises -- industry is a partner in education.) By 1985, 85 per cent of those employed had completed a vocational or professional education.

The impact of this planned upgrading of the overall employment structure will be that in 1990 4-5 per cent of all employees will be specialists in informatics, 15 per cent will be highly competent and use informatics in their occupations while 50 per cent will be able to use computers in their daily work routines[11].

The impact of "technopoles" as demonstrated by the *French* study was that as centres of training/research and producers of high technology, they had attracted large numbers of small and medium sized firms, increasing employment of highly educated in the zone. In particular such centres had encouraged engineers and technicians to leave secure employment in large enterprises and set up their own small firms, usually high tech services to meet the needs of other large firms on the site. However, it did not seem that they were able as yet, in France to initiate industrial restructuration or contribute to regional development in a significant way.

To summarise as regards the impact of high tech industries on employment and qualification structures, we have noted the rapid growth in employment, a general rise in educational qualifications of the work force and in their functions, i.e. an increase in the proportions of graduates and engineers and a relative decline in skilled production workers. Both employers and employees confirmed that qualifications for jobs had to be higher in 1985 than in 1980. The impact of automation in particular required relatively more engineers backed up by lower ratios of technicians and skilled production workers. While such automation resulted in a surplus of some workers, these were dealt with by retraining and transfer. Innovating firms changed their structure more and had higher proportions of staff in R&D than other high tech firms who introduced but few innovations. The forecasts showed trends to ever-increasing proportions of graduates needed for employment in this sector.

11. See footnote p.19.

Thus it may be concluded that these high tech industries have made great demands on the educational system but they have themselves conducted massive training programmes to meet their needs. According to the samples of employees in these firms, training has been widely available.

Table 3. In-service traning given in the electronics industry to samples of employees

		Mode of Training		
	Percent Employees Given Training	Company Training Centre	Abroad	Other in Country
Indonesia	56%	41%	27%	32%
Cameroon	57%	70%	20%	10%
Republic of Korea	37%	40%	37%	23%

It is evident that such industry makes a major investment in the human resources of the country concerned, whether it is a foreign company or a local one.

The need to employ foreign staff in top (highly paid) posts is still prevalent in high tech industry, as is training abroad and use of foreign instructors in training courses. Shortage of this level of personnel has been one of the factors contributing to the high rate of job mobility reported, as well as hijacking of staff and the creaming off of the best graduates by state universities and enterprises before they enter the labour market. Evidently one of the major problems to be addressed is how best to produce enough top R&D personnel and instructors.

3. The response of the formal education system

Where integrated industry-education planning is the norm, an immediate response may be expected from the education system. Such planned responses can be seen in the brief descriptions of the educational systems in the field of electronics in the German Democratic Republic and the Republic of Korea. However, even with planning and ready

availability of data, all was not plain sailing and further unexpected problems cropped up to which solutions had to be found or are still being sought.

Evidently where there is only partial planning or just a general policy and reliance on "market forces" to activate the private educational sector, it might be hypothesised that the response would be slow and inadequate to meet the real needs of industry etc. However, these hypotheses are not completely sustained as can be seen in the analyses of what actually happened in the (3-4) countries of this type which were studied in the research project.

Countries with integrated industry-education planning

German Democratic Republic:[12] The educational reforms of the late 1960s laid the foundations for the development of scientific and technological education in the German Democratic Republic. They included: 1) transition to a 10-year general polytechnic school for all where mathematics, natural sciences and vocational education account for 40 per cent of instruction and are taught by specialist teachers. One result of the reform is to be seen in the proportion of university students in technical science faculties -- in 1953 this was 20 per cent but by 1985 it had risen to 31 per cent; 2) occupational training for all before embarking on working life. In 1985, nearly 85 per cent of the relevant age group had completed a 10-year polytechnic education.

Such a reform could only be undertaken in liaison with enterprises who took the responsibility for practical training, i.e. a mass operation which in 1985 involved more than 5000 enterprises.

In 1969 when the governments of socialist countries decided to develop electronic calculating technology and adopt a standardised system, each country was designated to specialise in a particular area. In the German Democratic Republic, training programmes in rudimentary informatics were rapidly introduced in the university courses for mathematics, science, engineering and economics, and in the early 1970s training in informatics was spread to all relevant disciplines. Subsequently courses on Management Information Systems and

12. See the footnote p. 19.

Computer Aided Engineering were devised for specialists. However in order to put in motion a wide multiplier effect, at the end of the 1970s courses for university teachers and scientists on the "foundations and application of microelectronics" were organised as part of recurrent education. Centres of further training were set up, first of all in technical universities, but now include nearly all higher educational institutions around the country. At the lower polytechnic level, during the 1970s, knowledge and use of computers and informatics were added to the curricula, while during the period 1986-90 the rudiments of automation will also be phased in.

The rapid rate of change in computer technology requires a permanent system of continuing education. Further training in the field of electronics has acquired equal importance to initial training and education. In this, industry participates as much as the formal education system -- a number of large enterprises offer courses in informatics with a specifically practical orientation.

It may be noted that the German Democratic Republic education system has emphasised the spread of computer literacy throughout the population, not only the production of specialists. But in the latter domain too, the expansion of numbers of researchers in this field was planned under the policy document "Concept for Long Term Development of Science, Mathematics and Technology Basic Research up to the Year 2000". State research contracts were awarded in various forms of co-operation between firms, universities and departments of the Academy of Sciences. The latter and the universities are mainly responsible for basic research but half their resources are devoted to the practical application of the results of their own basic research. Moreover, these institutions have doubled their research capacity since 1970, their activities being combined with the training of students who comprise 40 per cent of total staff, i.e. they are a source of educated research manpower for industry. In fact, two-thirds of R&D workers are in enterprise centres which concentrate on applied research. The link between basic and applied has been recognised as all important since recently experiments have been made to set up basic research units for specific branches of industry. In addition, the smooth transition of research findings to industrial practice has been found to be assisted by establishing research complexes jointly financed by higher education and enterprises, a successful example of this being electronics. During

1983-85, 35 patents were registered by the joint efforts of the Electronics Department of Humboldt University and the Berlin Works for Television Electronics yielding a large profit to finance further research.

Even with global planning, as can be seen above, experimental solutions had to be sought to the problem of rapid transition of research findings to industry and to providing education/training which would result in a flexible and mobile work force able to keep up with technological change.

Republic of Korea: Even in the 1960s, the population of Korea enjoyed the advantages of a widespread educational network and a high literacy rate. However, the growth of industry, in particular the high tech sector, indicated plainly that there was a need to re-orient the system to produce more engineers and technicians. An effort was made to collect data on available programmes of different levels and types, including those of enterprises and identify mechanisms by which the co-operation of all those involved could be improved.

In 1965 there were only seven higher education institutions which offered electronics courses. By 1984, 392 high schools, 116 two-year colleges, 100 universities and 75 graduate schools had departments or courses in electronics. Enrolments increased from 1,959 to 79,528 over the period at the various levels -- the number of graduate students in particular expanding from four in 1965 to 1,699 in 1984.

Growth occurred at different rates for the different levels but can be linked to the promulgation of laws, which were not directed to formal education alone.

The lowest level of formal education where electronics courses are given is the high school. It is at this level that the most fluctuation in provision has taken place, for instance between 1977-1978 the number of courses nearly doubled followed by a drop in subsequent years, and again a rapid increase in 1982 followed by another drop. These fluctuations caused major problems of supply of teachers and equipment and in fact the schools did not have sufficient resources and the quality of the output was not high enough. Manpower statistics revealed that there was an oversupply of high school graduates and a shortage of more qualified staff.

Curricula at higher education level are designed for three kinds of technical staff: technical engineers (engaged in R&D), technologists (design, manufacture, sales) and technicians (measuring, maintaining, operating). The contents of courses and teaching methods are reviewed and adjusted from time to time.

Social demand for electronics courses has been high, particularly for computer engineering.

There are three possible types of training for skilled workers: the technical high schools, Ministry of Labour institutions and in-service company training, but there is a wide difference between the skills imparted in the first two and what is needed in industry. Therefore most large companies opted to provide their own training (they are obliged to make such provision by law), but the middle and small companies do not in reality comply with requirements nor do they recognise the usefulness of recurrent education. The Korean Technical Qualification Testing Agency was set up to standardise tests in the Ministry of Labour institutions and company training, and registers the diploma holders. The government subsidises this type of non-formal training.

The prompt response of the educational system to supply the manpower needs of the electronics industry is evident from the numbers of graduates produced and patents registered, which have been relatively much higher in electronics than for the education system as a whole. However problems have cropped up in calculating supply; too many were provided at the lower levels (with consequent waste of resources) while a shortfall is predicted at M.Sc. Ph.D levels (the Ministry has drafted a plan to double the current supply capacity). Also higher education programmes do not yet reflect new needs for robots, lasers and conductors. Thus attention is being given to establishing a monitoring mechanism which will detect new needs more rapidly.

Higher education in electronics does employ large numbers of scientists and engineers (it has the highest numbers working in R&D) but the emphasis is on basic research. Therefore over the period studied, enterprises started to invest substantially in R&D and rapidly increased the number of their research staff. Dependence on foreign firms for new technology much decreased and national firms learned to co-operate with each other in research (multinationals have fewer co-operative links).

Thus, in this country as far as integrated planning is concerned, we may note the non-participation of small and medium sized firms in training and the difficulties (as was seen in the German Democratic Republic too) of linking basic research in the universities with applied research needed by industry, as well as the problems in forecasting needs.

Countries with sectoral planning

Algeria On independence, educational policy in Algeria decreed there should be education for all. By 1987 81 per cent of 6 - 13 year olds were enrolled (but only 41 per cent of girls while there were also wide disparities between regions of enrolment from 59 to 96 per cent).

A reform of technical education was undertaken in the 1970s just when industry was expanding and needed technical manpower. However the proposal to phase out the previous Colleges of Technical Education and replace them by Secondary Technical Middle and Upper (lycées and technicums) resulted in enrolment in secondary technical falling from 36 per cent in 1962 to 1.5 per cent in 1979. Vocational training was also neglected in the 1970s. Thus policy in the educational sector tried to make up lost ground in the 1980s. Under the First Plan (1980-1986) a decentralised system of four major regional institutes for training of trainers and 268 centres was set up with the aim of implementing an apprenticeship system. Enrolments multiplied 2.5 times from 1980-86 but 58 per cent of the students were not in courses concerned with industrial technology but with office work, textiles, construction. Only 11 per cent were in electricity/electronics and 1 per cent in chemistry. Thus the supply of manpower from this source for petrochemicals is very limited. Under the Second Plan (1985-89), vocational education was to be designed to meet manpower needs -- 60 per cent of school leavers were to be offered work training. However the results of this latest effort are not yet known.

As to higher education, we have already seen in the previous section that in the 1970s, the universities were not yet developed enough to be of much assistance to the petrochemicals industry. However by 1989 40 per cent of students were in Technology and Applied Sciences (62,000 in all) and 7 per cent in the Exact Sciences (12,000). Shorter diploma technician courses are still relatively modest in number being

about 8000. In addition to this growth, the university is now able to educate more students at higher levels -- where in 1978 35 per cent of students were sent abroad for specialisation, in 1987 the proportion had dropped to 23 per cent. The number of postgraduates in technical streams in Algeria has gradually grown from 448 in 1979 to 2274 in 1987.

As regards petrochemicals in particular, since 1976 there have been several Ph.D students in polymer chemistry at the universities of Alger, Oran and Setif while at the lower level there is now a relatively large output in industrial chemistry, i.e. 3479 in 1989. Options like industrial chemistry are broad in content so that graduates are sufficiently flexible to be able to work in many types of companies e.g. detergents, refineries, cement, food, but in fact in 1983 60 per cent of Engineering Chemists found work in the hydrocarbons sector.

Thus when the plastics complexes began operation, the local education system was more concerned with Algerianisation of its own teaching staff and could not supply suitable manpower; now that the higher educational system can supply the graduates, demand from the sector is not as high.

Research in the higher educational system seems mainly concerned with the obtaining of Ph.Ds and is rarely connected with industry. Problems of understaffing and lack of equipment still exist. Publication of theses is much delayed or not done at all so that industry is neither informed nor involved. The petrochemicals sector (and other industrial sectors) has its own autonomous research institutes but the number of researchers in chemistry is low due to lack of suitably qualified staff. Under the 1986 Reform on research, employees in industry are to be oriented to participate more in research so that the petrochemical institutes, rather than concentrating on a research-training role, will have a research-development role in the future.

While sectoral planning has to a large extent been successful in Algeria, now that both petrochemical and higher education have developed their training/education systems, some of the courses are in direct competition and thus represent a waste of resources. The universities could well take over the basic courses, while at a higher level they could also co-operate in the research effort by sending Ph.D

students to the sector or enterprise laboratories. As development proceeds, new possibilities of organisation arise, which state sector bureaucracies may neglect or fail to recognise.

Countries guided only by general technological policy

In both the countries under this heading, i.e. Indonesia and the Cameroon, the enterprises asserted that specialised training should be left to them, and the educational system could not be expected to supply exactly what they needed. Thus, in both, as seen in the previous section, more than half the samples of employees had received in-company training (a much higher percentage than in the Republic of Korea). In addition, as noted in the Republic of Korea previously, there is a high social demand for technological types of education. Thus the enterprises, the education system and individuals all shared common aims in promoting development in the modern sector but in these two countries the technological starting base was lower and educational institutions lacked facilities, equipment and teachers in the technology, maths and science fields.

Indonesia However, turning to Indonesia, here the teaching of telecommunications/electronics receives the support of a wide variety and numerous institutions. Overall, during the period 1970-87 Indonesia made significant progress in education, by 1987 enrolment rates in primary, junior secondary and higher education reached 96 per cent, 52 per cent, 33 per cent and 7.4 per cent respectively. Enrolments in technical schools accounted for 30 per cent of senior secondary enrolment but these institutions could only offer places to 63 per cent of applicants. Private institutions play a very important role in education with 65 per cent of total enrolments at secondary level and 56 per cent at tertiary.

Electronics courses began at the Institute of Technology, Bandung, in the 1960s, and have spread to most state universities but comparatively few of the private, i.e. in 1986 there were 46 state universities (of a large size with an average of 8500 students) and 665 private universities (small with an average of 780 students each). Only 30 of the latter give electronics/ telecommunications courses. The

shortage was recognised by the government which recently established a series of polytechnics -- there were seven in 1982 which had grown to 32 in 1988; all teach electronics.

In the sample of educational institutions studied in the research project, the response of the educational system is quite clear: from 1980-85 the number of electronics courses and students enroled doubled. Teaching staff increased correspondingly and by 1985 their qualifications were much higher. However, education in the engineering and technological fields faces many problems, in particular those of drop-out and repetition: at diploma level only 17 per cent of those enrolled graduate, and the average length of time to complete a 4-year degree programme in Engineering is 6-8 years. Many students have to work while studying. Some government departments have thus initiated programmes to train their own technicians and in fact almost all Ministries organise non-formal courses. Private non-formal institutions teaching electronics/telecommunications are widespread. However, the latter complain that the Ministries are setting up courses which duplicate their own.

The educational system has not been able to supply enough high level R&D and Design staff for industry. Sources of supply are limited in that the state universities carry out some applied research and co-operate with state enterprises while the private universities concentrate mainly on basic research and have little contact with industry. However, in recent years, a few universities have begun to take on the role of "trainer of trainers" i.e. to give courses to instructors in industry.

There are countervailing forces to the efforts made by the education and industrial training systems to supply manpower, i.e. the statistics show quite a large proportion of technical graduates and diploma holders take up clerical work (37 per cent of those with Engineering degrees) and that the public services employ most of the educated work force. This situation must contribute to the virtual technological stagnation of private sector industry (as noted in the previous section) and to the low level of R&D activity.

Public/private segmentation in the education system reinforces that existing in industry and it was concluded that this is hardly conducive to the development of an integrated network of satellite suppliers to the giant telecommunications industry which complains of lack of local

technology. The policies of import control and protection of infant industry (while at the same time providing no R&D incentives) resulted in virtual stagnation which the educational system (whose output of graduates goes mainly to the public sector) could do little to counteract.

Cameroon, on the other hand, was open to the import of technology, control being exercised on the output of the industry. However, most secondary schools in the country are private and their growth much influenced by strong social demand. This is particularly the case for the technical schools, 71 per cent of which were private in 1983 and received 2-3 applicants for each place. Practical training is not generally available either at secondary or higher levels and there is a high rate of drop-out and repetition caused by lack of maths and science teachers and absence of equipment and facilities. The higher education system produces too few Science and Technology graduates and the Polytechnic, an élite establishment as regards resources, comprises only 2 per cent of the total student body. There is, in any case, no petrol studies option in any of the courses. Hence both oil companies and the government provide scholarships for study abroad. It was thus not surprising that the enterprises in the survey reported shortages of experienced engineers, computer operators and R&D staff. In addition, some of them were not satisfied with the primary and secondary education of their employees.

The above situation led to a mass training effort on the part of the oil industry concentrated in the first years mainly on producing skilled workers for operations and maintenance. The local refinery training centre has made a major contribution but by 1985 found that training needs were becoming ever more complex: 16 types of training were given including computers, law, management. Local training now requires more assistance from the higher educational system and the co-operation of the industry as a whole.

Conclusions

(1) Whether there was planning or no planning, the formal education systems have made a major response to the manpower needs of new modern sector industries. Evidently in those countries where schools/universities were not adequately equipped, the results were insufficient in quantity and quality. Also, where there were large

proportions of private institutions, there was some duplication and over-supply at the lower levels, while at higher levels, there were not enough graduates capable of R&D and design.

(2) Expansion was assisted by a high level of social demand, i.e. even in countries with a low technological base, the younger population fully appreciates the importance of and career opportunities available in the high tech sectors. Thus response is not generally impeded by culture or traditions (the case of Algeria was an exception).

(3) Where there was little or sectoral planning, response as regards R&D in the educational system was generally inadequate. Sectoral planning also resulted in duplication of education and training efforts.

(4) The most important conclusion to be drawn is that the education system cannot make an adequate response on its own: industry must participate. In some developing countries, large enterprises have carried out most of the training in high tech sectors and have had to make up for the inadequacies of the education system. However, they are often not asked to participate in decision making in education. Their training is not, for the most part, incorporated into a system of recognised qualifications (which causes some staff to leave in order to take up university education). Also such training does not produce an adequate number of R&D staff, and some medium and small sized firms do not contribute to the training effort.

. (5) The spread of innovation and research results from basic to applied and vice versa, and the distribution of work in the two areas, is a cause of concern to higher education and industry.

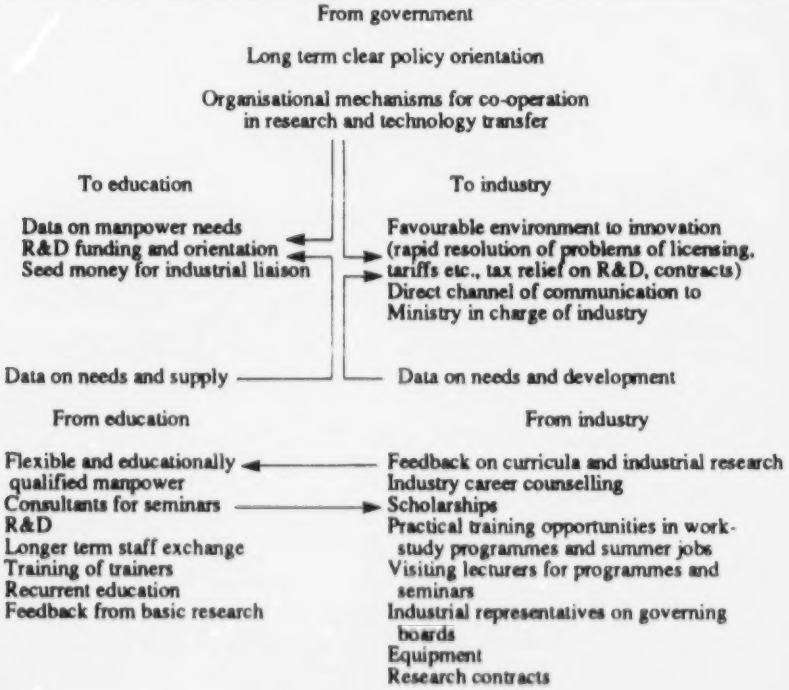
(6) Monitoring mechanisms generally were needed to:

- detect new needs for incorporation into curricula;
- bring to the attention of industry and the education system alike the need for recurrent education in certain domains;
- demonstrate the flow and utilisation of the stock of educated and trained technological manpower in order that measures may be taken or incentives offered to channel such manpower into sectors where it is most needed.

4. The state of government-education-industry relationships

The surveys conducted in this research project enquired into the actual state of links between government-education-industry and also asked what was thought desirable by those participating. Figure 3 gives an outline of the general requirements, as stated by the majority of institutions, enterprises and employees in the sample surveys.

Figure 3. Outline of requirements from state-education-industry for co-operation in high technology sectors


From government
Long term clear policy orientation
Organisational mechanisms for co-operation in research and technology transfer
To education
To industry
Data on manpower needs
R&D funding and orientation
Seed money for industrial liaison
Favourable environment to innovation (rapid resolution of problems of licensing, tariffs etc., tax relief on R&D, contracts)
Direct channel of communication to Ministry in charge of industry
Data on needs and supply
Data on needs and development
From education
From industry
Flexible and educationally qualified manpower
Consultants for seminars
R&D
Longer term staff exchange
Training of trainers
Recurrent education
Feedback from basic research
Feedback on curricula and industrial research
Industry career counselling
Scholarships
Practical training opportunities in work-study programmes and summer jobs
Visiting lecturers for programmes and seminars
Industrial representatives on governing boards
Equipment
Research contracts

The extent of co-operation which can actually be achieved between the state, education and industry obviously depends on policy, level of development, organisational ability, ownership of industry, motivation,..... and is not easily attained (some of the reasons being revealed below). This being said, one of the important findings of the research was that the desire to co-operate in order to develop the industry and the country was usually greater than one would have been led to believe by the state of the inter-relationships existing in the country, whether it concerned public/private sectors, state owned or multinational enterprises, management or skilled production employees. Thus it is clear that more could be achieved merely by organisational mechanisms and a willingness to experiment.

This is amply demonstrated by the *German Democratic Republic* study. While the planning, policy, organisational structure, infrastructure all exist to provide a favourable environment for linking education with industry, yet it has been necessary continually to innovate with different forms of co-operation for different levels and types of education and training. The fact that little could have been achieved without co-operation has already been made clear in Part II.C together with the general outline of relationships between education and industry. Here, it should be emphasised that enterprise training centres and schools are state institutions and fully integrated into the system of qualifications. The importance of co-operation has become even more significant with the realisation that as much importance has to be given to further training as is given to initial training. The specific profiles of universities and other higher education institutions *together with their relations with industrial enterprises* are taken into account and form an important basis for long term plans for the development of teachers and specialists. Many different forms of co-operation are used but latterly they are increasingly developing on the basis of formal contracts. These may cover research projects, the temporary exchange of staff or the acceptance of secondary school pupils as a special type of "apprentice". These pupils will sit for the usual secondary school leaving certificate but take an additional specialisation. The object is not to give training that will result in specialists who do not have an adequate general education but to take those at the top of the class who can undertake

extra work and subsequently go on to become specialists. High technology requires a great measure of interdisciplinary knowledge and people who are accustomed to team work. The case study[13] describes a number of such experiments which might well be adapted in other countries where integrated planning does not exist.

It has already been made clear from the previous descriptions of electronics education and industry in the *Republic of Korea*, that while policy, planning, assistance with resources can result in a major response by education and industry as separate entities, yet co-operation is lacking.

According to the survey of enterprises R&D activity is largely self-contained (81 per cent of companies conducted research exclusively in the firm), only 7 per cent co-operate with universities or R&D institutes. Government tax incentives to R&D have been a positive factor here, whereas government grants to universities have obviously not been widely spread (only a third of electronics departments had an R&D budget -- much of it for basic research) and other resources have not been mobilised. There has been some co-operation in the organisation of R&D seminars and workshops (26 per cent of universities) and provision of consultant services (23 per cent).

However, no university reported helping industry with its training materials. The area where there was the greatest amount of co-operation was in recommending students for practical work experience, whereas the enterprises stated that they most frequently co-operate with universities to give advice on creation of courses and updating of curricula. The survey results showed that though enterprises attached importance to co-operation they were not satisfied with the present state of affairs.

The study concluded that this situation had arisen due to the difference in aims and values of the education system and industry, i.e. the universities have broad goals, while industry's are specific and sometimes of a short term nature. University structure is less flexible with little interaction between departments while industry has to deal with problems in interconnected areas. University regulations sometimes inhibit staff co-operating with industry on a long term basis.

13. Wolter, W. et al., ibid.

Industry tends to be secretive about its research whereas university staff want to publish in order to gain academic recognition. The government has become aware of the disadvantages of lack of liaison and is constructing a "science town" to promote industry-university co-operation and setting up an inter-university research centre for robotics.

This study is one of compartmentalised but parallel education and industry development, the education sector playing its part by supplying the basic manpower. As such it has been a success but as far as R&D and technological innovation are concerned, it is acknowledged that the country has a long way to go before it can compete with the major industrialised countries where university-industrial liaison has been a major area of interest and development for the last decade.

Following on from the Republic of Korea's problems of obtaining co-operation due to the differing aims of university and industry, it is relevant to insert here the experience of one of the technopoles in *France*. Most of the products made in the zone are industrial electronics designed for specific clients. Firms compete for this type of work and will not thus co-operate in R&D. This creates an obstacle to inter-industry exchanges on innovations though there was some mobility of employees between firms.

The most common type of liaison was between research institutes and industry. Many of the firms give R&D contracts, technological partnerships or just exploitation licenses to higher education institutions. The successive output of graduates from local colleges and universities forms the cement of the technopole -- the employees stating that they were attracted to the zone because of its role as intermediary between campus and industry. Sixty per cent of the firms had links with local education, 68 per cent accept students for practical courses, 24 per cent receive graduates to work on theses and 26 per cent of the firms have employees who teach part time in higher education. The percentage for students working in industry is higher than we have seen in the sample surveys of the research project. In addition, the local Polytechnic has estimated that it has indirectly (through its graduates and R&D) been the creator of 40 of the firms in the zone.

Where "compartmentalisation" was the characteristic of the situation prevailing in the Republic of Korea, "segmentation" is that which most aptly describes the public/private/ education/industry

relations in the telecommunications/electronics sector in *Indonesia*. As already noted, the state enterprises have successfully expanded and adopted new technology. They have close links with government departments and state universities, taking state university students for practical training, funding scholarships and collaborating in R&D. The state universities in turn obtain feedback on curricula, organise some training of trainers courses and also do a small amount of training of industrial researchers. The State Plan Repelita IV prescribed a combined major R&D effort, the state would undertake projects not carried out in the private sector. In practice most applied R&D is done by the state enterprises and universities.

Growth of private sector industries has been erratic due to tight control of imported technology and a low level of R&D activity. The private sector is isolated from government departments (who assist state enterprises with feasibility studies and adaptation) and from research institutes and universities (as regards R&D and training). They make use of the training centre of a large multinational company in the country. Also the survey questionnaire showed that private firms tended to train whatever R&D staff they needed on the job. These firms did not consider that they had a role to play in the technological development of electronics, while the state companies complained that lack of local technology was the most important obstacle to progress.

As the growth of public education has been tightly controlled, private education, formal and non-formal, has been the most flexible in meeting social demand for electronics courses. However, courses in the private universities are of a theoretical nature with few opportunities for practical work and any R&D is of the basic type. Needless to say, certain private universities complained of their isolation: they required assistance with curricula, opportunities to carry out applied research and arrangements with industry for the placement of students during course work.

At a lower level, institutions giving non-formal courses and secondary technical schools have made efforts to maintain good relations with local firms in order to obtain employment for their pupils and in this it seems they have been quite successful.

The effects of absence of a policy on R&D in private industry and lack of guidelines on university-industry-government liaison are apparent. In June 1988, the government took the first steps to creating a

more favourable environment for private industry by loosening regulations on import of technology, joint ventures are now permitted and it has expressed a wish for informal meetings with the private sector. Given the situation described above, it was not surprising that participants in the surveys (employees, enterprises and academic institutions) thought that the government should take a more active role in the organisation of R&D in both universities and industry i.e. once again the lack of coordination mechanisms and stimulus to innovation has been highlighted.

Given that the petrochemicals industry in *Algeria* was developed before the higher educational system had coped with its own problems of Algerianisation of teaching staff and establishment of high tech courses, and that the sector set up its own training and research institutes to supply the manpower it needed, the need for co-operation only began to be realised in the mid 1980s. At that time a series of meetings were held between the Ministry of Higher Education and productive sectors to create inter-sectorial commissions. The results so far have usually taken the form of agreements between a university and an industrial complex whereby students are given practical work and industrialists lecture in the university. In 1986 the universities of Constantine and Annaba signed an agreement with the research laboratory of the Skikda complex whereby the universities allow technician employees to prepare theses and in turn the universities are allowed to use the facilities of the research laboratory.

So far it has been rare for the research results produced by universities to be used in industry -- as noted previously, often industry does not receive copies of theses. It has been found that it takes about five years in industry before a graduate can introduce any innovation (there have been a few adaptations of imported technology).

In addition, university petrochemical courses have not been much modified following suggestions from industry. While the latter is satisfied with the quality of recruits from specialised sector institutes, it is only partially satisfied with those from higher education.

Neither the productive sector nor the higher educational system has a positive view of the other: the productive sector considers higher education as too theoretical and more concerned with reproducing itself than with contributing to development. There is also the fact that many of the original employees in industry are under-qualified and fear the

young graduates. Higher education staff, on the other hand, point to the over-riding sectoral interests of the industry which ignore the long term global strategic view of education which needs to produce broad-based and flexible graduates.

The above situation echoes that found in the Republic of Korea. It might be useful if various innovative forms of co-operation were set up here too so that each sector may learn to appreciate the value and opinions of the other.

The oil sector in the *Cameroon*, implanted in a mainly agrarian economy and of relatively recent date (it is now about ten years old), has so far made only very basic links with other agencies in the country. The survey showed that the main forms of co-operation remained bilateral i.e. university-government and industry-education. Industry-government relations are confined to policy for the exploration and production of crude and licensing arrangements.

Industry-education relations are for the most part limited to granting of fellowships for higher education and holding of seminars where staff from other firms and from educational institutions may be encountered. The exception to this is the Cameroonian refinery which accepts both higher education and secondary technical students for pract2ical training. Many of the enterprises are multinationals and it might be thought that this is the reason for their lack of liaison but in fact, in the survey, interest was expressed by multinationals in exchange of staff, project execution and in consultancies for university staff. It seems that if a co-operative mechanism existed, it might be possible to develop useful relationships. A major problem in establishing co-operation with higher education is the absence of a petroleum studies option and R&D activities in the university. The refinery felt that the time had come to develop such an option, with the co-operation of the oil industry, on which basis an indigenous R&D capability could be built up. At a lower level, some of the firms stated that they were not satisfied with the quality of primary and secondary education but there is as yet no channel for them to express their opinions. This was supported by the results of one of the survey questions to the employees in that the overwhelming majority felt that the establishment of government-education-industry co-operation was the most important element if education was to be of service to the oil industry.

Conclusions

From the above country descriptions, it is obvious that there are usually wide gaps between what participants in the surveys desired in the way of co-operation and what actually exists. These were above all practical training opportunities for students, research contracts and equipment as far as educational institutions were concerned, while industry did not have enough high level R&D and design manpower. The two sectors evidently have common aims and yet do not sometimes clearly perceive this. We have found that though policy may prescribe a combined R&D or training effort, yet without the necessary support of coordinating mechanisms, tax incentives etc., the private sector universities are not able (though willing) to participate and private small and medium firms do not realise the advantages of participating. Much was achieved by policies for the expansion of education and industry in Korea, and by state enterprise/state higher education co-operation in Indonesia, but much more might have been achieved if all those concerned had been fully involved. It was clear that there was a need for mechanisms to:

- seek out possibilities for co-operation (e.g. some of the multinationals are willing to participate though up to the present, their co-operation has often not been requested);
- experiment with different forms of co-operation to suit different levels and types of education;
- establish some common goals for industry and university as a stimulus to co-operation;
- establish science parks/technopoles (or just by land management locate technical schools, polytechnics, science faculties, research institutes in the vicinity of relevant industry). Geographical proximity fosters research institute-industry co-operation and provides many opportunities for practical work to students;
- enhance the involvement of small private firms and private educational institutions.

5. Major implications for educational policy-making and planning

This part of the report will attempt to gather together the major implications for the educational sector into a general scheme. The implications within the context of individual countries are given in Part III of this study -- present preoccupations may differ by level of development of the country, industry and educational system, yet a broad pattern can be discerned.

This being said, it was also evident that it is important to recognise the moment when different types of policies and planning should be emphasised. Inevitably where modern sector industries are "imported", they must develop rapidly to obtain a return on investment and hence are sometimes way ahead of the educational system in training, production of graduates and research. The educational system may later be able to develop to the extent that research and training policies can now be reoriented (Algeria, the private educational sector in Indonesia). But sectoral planning may have brought about an established bureaucracy which considers itself autonomous and the gap between the educational system and the industrial sector may become entrenched (Republic of Korea, Algeria). They may even feel that they have quite different goals.

Educational planning is broad and long term while sectoral planning is specific, short term and often, due to availability of resources, the most powerful (Republic of Korea, Algeria, Cameroon). It is evident that sectoral planning has been successful for industrial development and has resulted in some useful planning work such as surveys of manpower needs and training facilities but these are not always fed back into the educational system in time (Republic of Korea) so that expansion has to be checked and then restarted. The studies show other disadvantages: multiplicity of autonomous training and research institutes under various ministries, duplication of courses in education, industry and non-formal sectors, weakness of secondary technical, disappointing results in producing R&D graduates and innovations. A phenomenon that was also noted was the progress made by state sectors while private education and industry lagged behind (Indonesia, Algeria, France). As the Algerian study pointed out, the world economic climate has worsened, countries will have to limit the number of postgraduate fellowships

abroad, training contracts, import of technology, employment of foreign staff, and depend much more on marshalling *all* their resources for development.

Thus without exception, the studies came to the conclusion that policy-making would have to cover inter-sectoral industry-education-private-public coordination. The mechanism chosen would depend on the context and the studies give some examples. Lest it should be thought that private industry and education would not welcome government intervention, it must be stated that this is most definitely not the case, they particularly request guidance for the development of the R&D function. Also, although in the Algerian case study, it is pointed out that the multinationals under "product in hand" agreements leave no room for the participation of the educational system in training, on the other hand, where they were specifically questioned on their attitudes to co-operation with the local education system (Cameroon), they were ready to participate in certain areas -- locally recruited staff cost much less than those recruited from overseas so any activity which increased the numbers of local personnel would generally be welcomed.

As regards the need to incorporate the private sector in any coordination mechanism, it was noted in some countries that private education had expanded faster (not being under Ministry financial control) than the public sector to meet the needs of high tech industry (Cameroon, Indonesia) though the quality and the bias towards the theoretical was criticised. This is important in view of the current interest in privatisation of education to increase the overall educational resources within a country and decrease the burden on the state. Policy should make it clear that all sectors are partners, all are represented (there are no poor relations) and they share common goals, although they may contribute by fulfilling different complementary roles. This would help to narrow the gap between education and the productive sector. It would also assist, with the expertise of the relevant sector, in orienting the educational system in specific areas of high tech. In this respect, the study on Indonesia was particularly interesting in that the various educational institutions had already assumed certain roles in telecommunications/electronics education, but no thought had yet been given as to whether this was the right balance, and the private universities were uncertain of their future direction. The present situation is:

- Private universities concentrate on electronic theory in their courses and on basic research. In the future some of them would like to specialise (but on what should they specialise?).
- Polytechnics emphasise control systems in their courses.
- State universities give emphasis to telecommunications in their courses and expect their education to be of a general level. They carry out more applied than basic research.
- Non-formal private institutions giving short courses wish to concentrate on telecommunications in the future.

Where resources are limited, it would be unwise to allow education to cater mainly to the large state telecommunications sector, while other private electronics firms are stagnating for want of R&D staff and innovation.

Several of the studies mention the need for interdisciplinarity which is a feature of high tech industry (German Democratic Republic) and that planning should aim at building up national teams (which cannot be achieved under sectoral planning -- Algeria). National coordinated policies should thus cover data collection, analysis and dissemination on availability and needs for training and research, assisted by local/regional level education-industrial liaison centres. Policy should also monitor salary structures and conditions of work, which may deform the manpower structure e.g. in the Republic of Korea, full-time lecturers earn more than R&D personnel in industry yet their capacities for R&D are not fully utilised in the universities. Also the conditions of work in the public sector in Indonesia are considerably better so that even the attraction of initial higher wages in private industry cannot halt the flow into state services and education. The programme of Arabisation of the teaching staff of universities in Algeria has brought criticism that the higher education sector is more interested in reproducing itself than in meeting the needs of industrial development. A policy is needed to ensure that the state and education sectors do not monopolise the best of potential high level manpower, but share them with the private sector.

(a) Policy and planning in the formal educational system for scientific and technological development

While it is accepted that the formal education system gives the basic grounding in the various disciplines, and the productive sector accepts responsibility for specialised training, yet both parties agreed that proper education could not be given because of lack of opportunities for practical work from secondary up to higher education. All the studies emphasised this though of course the situation was much more critical in developing countries. It was felt policy should foresee education-industry liaison to provide laboratories/workshops to serve a network of educational institutions, contact with the industrial training sector so that students may participate in job training programmes or take vacation jobs, etc. The educational system should reconstruct its qualification system to give credits for practical work programmes, industrial training programmes (as in the Republic of Korea) and introduce a modular system i.e. it should become more flexible and practical so that it can more readily adapt to new needs. The same criticism has been levelled at sectoral training (Algeria) where the system has become bureaucratised. Cameroon in particular suffers from the inflexibility of the qualification structure in that employees have to leave their jobs because there is no further hope of promotion.

The same flexibility and willingness to innovate is required in updating curricula (even where liaison committees exist which are composed of industrialists (as in the sectoral training system in Algeria) courses are not adjusted quickly enough (the same was true in the Republic of Korea). More modern methods of instruction are required in high tech areas, including seminars, audio-visual, visits to industry.

While it is acknowledged that the weakness in technical education (particularly at secondary level) in developing countries can only be overcome in the long term, again it was emphasised that this did not preclude certain short term measures being taken wherever conditions were favourable -- school sponsorship, loan of equipment, co-operation agreements with industry. Again the stress is on the flexibility of the educational system and a clear policy formulation would encourage such innovations.

Policy should foresee refresher courses for teachers to impart more technical skills and linguistic capabilities (e.g. in Algeria it has been found that the limited linguistic capabilities of teachers in science and technology is impeding the dissemination of new knowledge). Given the multiplicity of sources of technology, it is clear that language training is imperative for researchers and teachers.

(b) Policy and planning for continuing education

The importance of continuing education is not always appreciated even in high tech industries (Republic of Korea in particular) so that a clear policy would favour employees wishing to keep abreast of new knowledge. In this domain, flexibility is even more important. Differentiated training has to be given by level of education and specialisation (see the German Democratic Republic study) and a willingness to continually innovate and experiment with different forms has been found to be a necessity for technologies in which there is rapid change[14]. Again a modular system, incorporated into the qualification structure, would provide more motivation.

In certain countries, it has been found that the universities are performing an important role in providing training of trainers courses, so that policy-makers might reflect on whether this may be one of the means whereby higher education could most usefully co-operate with industry in development.

(c) Policy and planning for research

The problem of production of sufficient high tech R&D staff in developing countries is critical but often no policy exists to guide those working in education and industry. Both parties have requested that the government should take a more active role in the organisation of R&D.

Again as with the content of courses mentioned above, policy should outline the general roles, and arrangements covering industrial liaison, with the stipulation that initiative and flexibility are to be encouraged.

14. In this respect, see also United Nations: Overall Economic Perspective to the years 2000, Economic Commission for Europe, United Nations, New York, 1988, p. 20.

Such general policies as "R&D is to be a combined effort and that state institutions will undertake what is not carried out in the private sector" are insufficient in that state enterprises and universities, and the large multinationals have most of the funds for R&D and other private firms and higher educational institutes may do very little.

The present role of universities in research emphasises the basic and theoretical but the balance may be more equally basic/applied where co-operation with industry has been established (usually state university/state enterprise). The problem again remains the private sector where large numbers of graduates may be produced and where in medium and small sized firms there is a lack of high level R&D staff. There is also the problem of competition and confidentiality of research work in the private sector to be overcome.

Policy-making thus has to provide guidelines[15] for education-industry research collaboration, provide seed money for industrial liaison in order to initiate the process, give advice on sharing of intellectual property rights and the resources to be devoted by those co-operating in the research. The educational institution may find a way of building on its basic research activities by holding seminars to establish certain common basic problems of local industrial research which could be tackled by the university, industry contributing to a pool of funds for this purpose. Information on the results would be generally disseminated. Bureaucratic obstacles were also cited -- university budgetary procedures needed to be more flexible if staff were to be motivated to carry out more R&D (Republic of Korea).

In most of the studies the impression given was that universities need actively to be encouraged to venture out of the basic/theoretical/training type of research and where they have been part of state policy and planning, this has occurred.

15. This matter is dealt with in some detail in the Indonesia study.

Conclusion

This section has emphasised the importance of overall integrated policy-making to evaluate and make full use of all the resources for education, research and training at the country's disposal which may assist scientific and technological development.

The need for coordinating mechanisms at central and regional/local levels and guidance and stimulation of co-operation have been highlighted. Such policy and coordination does not mean bureaucratisation: flexibility and initiative are all important at the local level. In high tech areas, experiment in different forms of co-operation for different levels of education and specialities is all important. However, policy should take account of such factors as the high degree of education-industry co-operation found in conditions of geographical proximity, overall salary structures, the qualification structure, the roles which sectors/institutions are best suited to perform, linguistic capabilities. After having provided the most favourable environment possible in the context, it remains for the policy makers to obtain feedback (channels of communication for the private sector are often lacking) and attempt remedial action.

C. Summaries of the case studies

Case study No. 1

Technological development in the microelectronics industry and its implications for educational planning in the Republic of Korea

1. Introduction

The study had the following objectives:

1. To identify the role technological policies of the state and of private industries have played in the development of the microelectronics industry;

2. To identify the impact of technological development on automation, employment and the qualification structure of the work force in electronics industries;

3. To examine the way programmes of training and research development in the country have responded to new needs for skills;

4. To ascertain the extent to which government-industry- education interfaces have helped develop the education and training system to assist technological development in microelectronics.

The first three objectives have been dealt with in two ways: a macro approach giving the national scene and a micro approach where we have analyzed the perceptions and experience of individual employees, enterprises and academic institutions offering courses in electronics based on representative sample surveys.[16] The government-industry-education interface has been analyzed only on the basis of the perceptions and opinions of the employees, enterprises and academic institutions. In the following sections we shall try to list the principal findings on the above issues integrating the results of the analysis based on the two approaches, and derive implications for educational planning.

2. Industrial and technological policy in electronics

The electronics industry of the Republic of Korea is expected to continue its rapid growth and structural shifts in the coming decade. According to KIET[17] forecasts, the electronics industry's share in total manufacturing production will increase. Microelectronics will play a central role in the development of the electronics industry. Semiconductors, computers and peripherals will lead growth through their widening application to consumer electronics and telecommunications equipment.

This is so because of the history of the evolution of this industry and the corresponding technological policy. The government's openness towards outside investment encouraged foreign investors to take advantage of the cheap but qualified labour of the Republic. Due to lack of material resources, especially energy, Korea is emphasizing high technology sectors such as VLSI chip production although the head-on competition with economic giants like Japan and the U.S.A. has been a source of controversy within the country in respect of industrial and technological policy.

16. For details of the methodology and the instruments please see: Sanyal, Bikas C. and Yu, Hyun-Sook, *Technological development and the micro-electronics industry and its implications for educational planning in the Republic of Korea*, Paris, IIEP, 1989 (IIEP Research Report No. 72).

17. Korean Institute of Electronics Technology.

The semiconductor industry constitutes 35.1 per cent of production and 55 per cent of exports of total electronics production. Even with the rapid development in wafer fabrication, the semiconductor industry in the Republic is still at the beginning stage, because of emphasis on simple assembling with imported chips. The chip packaging technology is almost as developed as in Japan or U.S.A. but design, wafer fabricating and testing technologies suffer from lack of accumulated know-how, R&D, manpower, equipment and related software.

In respect of the second most important electronic product, namely, computers and peripherals, Korea made rather slower progress. The country started producing computer hardware only in 1975. In 1982 Goldstar produced the first micro computer. Since then large scale production of personal and micro computers has started in several firms. In 1983 computers accounted for 3.8 per cent of total electronic production and 3.9 per cent of total electronic exports. Computer peripherals dominate the output because of the relative advantage Korea has gained in assembling. The rapid growth of the computer industry in Korea has been possible largely due to a good export performance on contracts with original equipment manufacturers (OEM), revealing the weakness of the industry in producing own brand personal computers. More than 90 per cent of exports are monopolized by the local subsidiaries of the big foreign firms, while almost all of the domestic demand is met by the products of the purely local makers.

What is more striking is the under development of the software part of the industry. This is mainly due to the legal loophole in the software copyright which allows indiscriminate copying of foreign software thereby providing strong disincentive to local development of software. An agreement has however been reached between Korea and the U.S.A. to protect software as from July 1, 1987. The number of software firms has increased recently, with a corresponding increase in software engineers and scientists.

All the computer firms co-operate with foreign firms in the form of joint venture or licensing agreements. The government under the pressure of foreign computer firms had to liberalize computer imports even to the extent of free import of computer hardware in 1985.

The electronics industry in Korea, has, as usual, the highest R&D/sales ratios among all the industries. In 1983, this was 3.10 in percentage terms. Semiconductors had the highest at 9.22 in 1985. This

is, however, less than the figures in U.S.A., Japan or Federal Republic of Germany. Domestic semiconductor producers co-operate with foreign firms in respect of research and as has been indicated before, have established subsidiary research firms in the Silicon Valley of U.S.A. for semiconductor development. In respect of computers also the country is dependent mostly on foreign research and development. However, in 1982 seven companies teamed up to incorporate the Korea Software Research Co-operative. A semiconductor research co-operative has also been set up by a group of firms producing semiconductors. These joint R&D activities are motivated by the need to reduce risks by pooling R&D resources.

Our analysis of the evolution of technological policy for the microelectronics industry reveals that Korea attempted to emphasize the role of the development of science and technology through its education system and other methods in achieving technological progress. The setting up of the Ministry of Science and Technology (MOST) in 1967 and the subsequent industrial and corresponding science and technology strategies along with the series of laws enacted for the promotion of science and technology helped implement the technological development programmes. This was further facilitated by the establishment of a number of institutions of science and technology around the country keeping in view the requirements of the microelectronics industry. The latter received its first special attention in the Electronics Industry Promotion Law promulgated in 1969 and the subsequent eight-year development plan (1969-76) for the electronics industry.

In the beginning however, dependence on imported technology was almost total with a very low R&D emphasis. It is guessed that until the late 1970s R&D activity in microelectronics was less than for the electronics industry as a whole. Things started changing in the 1980s. The Government revised the Electronics Industry Promotion Law in 1981, planned for rapid progress and established an Electronics Support Fund to be financed by public and private contributions. In addition to liberalization of trade policy in free import of finished products as mentioned before, the government provided tax incentives for investment in R&D by allowing firms, among other benefits, to set aside a certain percentage of profits for R&D investment which will be tax exempt for a given period. Financial loans have been made easy with the provision in commercial banks and state owned banks of ear-marked

funds for R&D. Venture capital companies have also been set up for the purpose of providing research and development. In addition there are other direct fiscal incentives for research and development. The Korean Institute for Electronics Technology with a relatively comfortable budget and adequate manpower played an important role in developing new technologies. Merged with the Korean Electrical and Telecommunications Research Institute with the new name of Korean Electronic and Telecommunications Research Institute, it is now drawing up the master plan for VLSI and mainframe computer development. Collaborative R&D activities between government affiliated institutes and private firms are also helping the industry. In addition to R&D, the government's procurement policy and liberal foreign investment and technology import policy have helped in the development of the industry.

However it is also true that technological policy still has many challenging problems to solve. The microelectronics industry is characterized by high risk and low return. This discourages R&D investment by individual firms. But it is also a characteristic of the microelectronics industry that technological superiority is the key to increasing returns to investments. Technological superiority guarantees monopoly power in the market, which is the source of economic rent. The life cycle of the microelectronics product is very short and the returns to investments decline sharply over the cycle. Technology is the single most important factor in determining the position of the product in the life cycle.

The primary objective of technological policy in Korea should aim at expanding the absolute size of R&D expenditure on the one hand and allocating it in the most efficient way on the other. In order to achieve the former objective, the efficacy of current incentive measures should be carefully assessed and adjusted. Some suggestions are put forward here:

(i) The Government's financial contribution to R&D needs to be increased. Fiscal subsidies and loans have been steadily increased but are still insufficient. The externalities of technology often cause under-investment in R&D in the private sector, particularly for basic R&D which is not directly linked to profit opportunities. This explains the increasing role of fiscal support for R&D in other countries.

(ii) Tax reduction and exemption has limits as an incentive to R&D because firms making a loss cannot benefit from this incentive. Another limit of tax incentives is the ceiling on the total amount of tax benefits allowable to a single firm. Under present regulations, total tax benefit in one year cannot exceed 30 per cent of the firm's corporate tax for the same year.

(iii) Financial loans for R&D should be provided on the basis of credibility of borrowers. Most of the small and medium sized firms in Korea suffer from shortage of real estate mortgages, which is the biggest constraint on obtaining loans under the current financial system.

The second objective of technological policy, that is, to allocate R&D resources efficiently, is as important as expanding the total amount of R&D investment. Technological policy is activity-specific -- as opposed to industry-specific -- and as far as the private sector determines where to invest, the government has no direct leverage in allocating private R&D resources. But it is still true that the private sector's decision-making is affected by public policies, directly or indirectly.

The strongest instrument in controlling allocation is decisions on research areas supported by the government budget. It is often criticized that the government is not providing enough support for the development of industrial technology which is more closely linked with production of marketable goods. This criticism emphasizes that decisions on research topics by the government should consider economic feasibility as well as purely scientific viability.

Another role of the government in the efficient allocation of R&D resources is to organize and encourage co-operative research in the private sector. Acute shortages of competent scientists and engineers in Korea calls for joint R&D efforts by public research institutes and private sector firms.

Analysis of our survey data demonstrates that technological development in microelectronics in the Republic of Korea depended on a complex combination of factors. Size of firms, type of firm, sales to working capital ratio, sales revenue to employee ratio, the ratio of professional and managerial staff to total number of employees and the educational background of the employees had influenced the evolution of technological change measured through the introduction of "turning point" products and processes of production. Since our primary concern

is the role of education we note that those firms which have a higher proportion of university educated manpower have introduced a larger number of turning point products and processes of production. It was also noted that in recent years small size firms have been more innovative. It was also noted that the innovation capacity of domestic firms has increased substantially in the last plan period (1982-1986) than in the previous ones. The dependence on import of technology has also decreased drastically in recent years. The correlation between the development of education and technological processes, although not very obvious, cannot be ignored.

The future plans for introduction of new products and processes give some indications to educational planners on the areas of content in electronics to be emphasized for product design and manufacture, and expertise in the production process. In respect of computers and their peripherals, major product items are sophisticated micro computers, colour cathode ray tube terminals, laser beam printers, and high speed modems. In the area of parts and components, semiconductor devices take a very prominent role. In the area of production processes, automation is being given priority. Introduction of numerically controlled machines, robots and unmanned transportation system is being undertaken by some firms.

The educational implications of this development are important. So far, however, the education system has intervened in the formulation of technological policy and its implementation in a very limited way. Only 40 per cent of academic institutions (public and large institutions) had some role in the choice of products to be developed but no role in the marketing and contractual policies. However, R&D institutions of enterprises did have the most significant role in formulation of technological policies. Since these institutions are staffed by people from the formal education system the relationship between the education system and this aspect of technological development is indirect as has been mentioned before. The role of academic institutions has also been marginal in the implementation of technological policies. Only in the area of development of new products have they played some role. The academic institutions also assisted in feasibility studies and with production technologies for the new products to be developed.

The effect of education was more marked when we analysed the number of patents registered by the employees. It is the university graduates who registered the largest number of patents on average, implying the importance of formal education in accelerating technological change. The role of academic institutions in initiating any change has been insignificant. It is the foreign company which took the initiative in most cases followed by the domestic firm.

This shows that universities are expected to play a more important role in promoting technological development in the country -- in initiating change, formulating policies, implementing them in co-operation with the government and industry. At present the situation is mostly dominated by the enterprises, initiative coming from the foreign companies, and implementation being ensured by companies with important support from the government. The way the universities and academic institutions can play their role will only be better known after we have examined the way technological development influences the qualification structure of the employees of the firms.

In respect of research activities for technological development, individual enterprises cannot afford the cost. Hence enterprises with common research needs should share the costs by taking part in co-operative research efforts as is already being done in software and semiconductor development (see above). Moreover, research is very time-consuming and the recruitment of qualified manpower makes the staffing of projects problematic. For all these reasons, research and development tasks are usually beyond the scope of individual enterprises. Furthermore, when enterprises conduct independent work, there may be much overlap and duplication of efforts. This could be overcome by strong joint co-operative efforts between industry and academic institutions and other related agencies.

The survey results were somewhat disappointing in this respect[18]. In determining the choice of electronics products, only a third of the academic institutions played any role and overall they were not perceived as initiators of change. However, enterprises were becoming more aware and realistic about their research capability. A good number

18. Sanyal, Bikas C. and Yu, Hyun Sook, ibid., Chapter VII, Table 2.

of them gave the highest degree of importance as regards the role of the government in bringing about change in the technological environment to "government grants to universities".

In the next ten years, microelectronics will become more highly sophisticated. Thus far, development of the electronics industry has been made possible by the use of imported turn-key base technology. Both for reasons of the high cost of such imported technology and growing protectionism, it is inevitable that local research capability will increase in the future.

Economic profitability is the most important motivating factor for development of local technological capability, the lack of which is the main reason for import of technology.[19] The country therefore has a need to emphasise a technological policy which will make it more self-reliant. The implications of such a policy for employment and the qualifications structure as perceived by enterprises, institutions and employees are discussed in the following section.

3. Impact of technological development in microelectronics on the employment and qualifications structure

The Republic of Korea has undergone significant changes in its industrial structure since the 1960s. These changes have influenced employment structure as well. In 1963, 63 per cent of employed were in primary industries. This fell to 30 per cent in 1983. At the same time employment in industry increased from 8.7 per cent to 23.3 per cent. In 1960 the proportion of employees with less than lower secondary education was 82.7 per cent and in 1980 this dropped to 52 per cent showing the improvement in quality of the workforce. Nowhere were these changes so significant as in the electronics industry of which microelectronics is a part. The total number of employees in electrical and electronic industries increased from 181 thousand in 1976 to 204 thousand in 1982. The proportion of engineers increased during this period whereas that of craftsmen was reduced, showing the increased demand for professional skills.

19. Ibid., Chapter VII, Table 16.

Computers are being used for operational purposes rather than for strategic and management control, implying that operators' employment will be affected by the initiation and expansion stage of computer diffusion. It is the large scale enterprises which use computers and NC machines. The automobile and electronics industries are the largest users of robots having a corresponding impact on employment. The automobile industry, ship building firms and some construction firms are using CAD/CAM systems.

However, the employment effects of automation in Korea are not yet certain. If automation of various degrees lowers production costs, the extent of harm in transitory increases in unemployment caused by automation is far less than that from the chronic unemployment caused by nonautomation and consequent deterioration of trade competitiveness and hence underdevelopment. In respect of policy, two tasks are called for. First, the development of the microelectronics industry as a supplier of automation equipment should absorb partly the labour released by automation. The other task is to reduce import of plant and equipment because this means export of employment.

In respect of manpower demand and supply, it is noted that according to the optimistic assumption where annual growth rate of production of electrical and electronic industry is set at 28.9 per cent, total employment will increase from 237 thousand in 1983 to 381 thousand approximately in 1991 with an annual increase of 6 per cent. Engineers and managers will have the largest increase rate of 24 per cent and 9.5 per cent respectively. According to the pessimistic assumption of 18.5 per cent annual growth rate of production, the total number of employees will change to 337 thousand approximately with an annual increase of 4.5 per cent. Rates of increase of engineers and managers are highest at 17.9 per cent and 7.8 per cent respectively.

The additional demand for workers by educational level has also been calculated for the two assumptions. According to the optimistic assumption, the annual additional requirement of university and college (JVC) graduates will nearly double during the period 1983-1991 from 4940 in 1983 to 9370 in 1991 whereas the demand for lower level graduates will decrease from 62,300 in 1983 to 47,900 in 1991. Comparison of demand and supply shows that there will be an oversupply of graduates trained in universities, JVCs and technical high schools accompanied by a huge shortage of R&D workers. However,

participation rates of educated manpower may change and with a 60 per cent participation there may be a shortage of workers of the former categories as well according to the optimistic demand.

The important policy implication for the above will be to promote programmes of training of researchers in electronics and monitor closely the demand-supply balance of other categories of manpower. There is no denying the fact that higher education system has to be more sensitive to the demand for manpower from the electronics industry.

The impact of technological change in microelectronics was examined in relation to employment structure, personnel recruitment and promotion, salary structure and job mobility based on the survey of employees and enterprises of microelectronics industry as well as academic institutes.

By classifying employees into types of functions, the change of their educational attainment from 1981 to 1985 was examined. The rise of educational attainment and the number of employees are evident, indicating that technological advance parallels manpower demand in microelectronics[20]. The relative decrease in demand for production workers suggests that manpower development be shifted toward higher education. This need was substantiated by the projection of manpower requirement responsive to technological advance. Automation, semiconductors, robots and computers are considered new frontiers of crucial importance and manpower demands in these are projected to increase steadily. This trend confronts higher education with the necessity of streamlining its system in a way that prepares it for an active role in manpower development in these fields. Higher education programmes have not reflected new needs -- such as robots, lasers and conductors, foreshadowing the necessity of intensifying investment in educational programmes dealing with them. Failure to increase investment means so much reliance on overseas higher education institutes, which is sure to be more costly. The result will be so much delay in developing self-search capacity for new technology.

In examining the impact of technological advance, it was found that education was most closely related to employment in R&D[21]. Among

20. Ibid., Chapter VIII, Table 1.

21. Ibid., Chapter VIII, Table 7.

others, academic and professional training was considered as the most crucial factor for employment in R&D, whereas experience, the school attended, acquaintances and recommendation were important criteria in other functions. Uniquely, promotion to higher posts in R&D was more heavily dependent on degree and certification. This builds up pressure for higher education institutes to continuously assess industrial needs. But it should not be a one-sided flow of information; industrialists should seek ways to make their needs known to educational institutes and government agencies.

The most important criteria for the recruitment of teaching staff for universities was academic and professional performance. But years of service was the most important factor for the promotion of academic staff.

In the wage hierarchy, R&D personnel rank second next to managers[22]. This indicates an increasing trend on the part of industrial firms to devote more resources to R&D. The full-time lecturers in universities earn more than R&D personnel of industrial firms, prompting competent technologists to opt for teaching rather than R&D. In order to retain them in R&D of industrial firms, their salary should be brought up to at least the level of full-time lecturer.

Job mobility is more frequently noticed among technicians, the graduates of junior vocational colleges than production workers. This means that they are more trainable to change jobs and upgrade their quality for positions which require a higher degree of professionalism.

4. The role of education in the development of the electronics industry and automation

It was observed that in the Republic of Korea the higher education sector employs the largest number of scientists and engineers in research and development, although the total number of research and development personnel is higher in the productive sector. Work for research and development is now almost equally shared between the higher education and the productive sectors. The most important field of research and development by numbers employed is engineering and

22. Ibid., Chapter VIII, Table 10.

technology. Natural science, medical science and agriculture play a lesser role. Among the productive sectors, manufacturing industries employ most of the scientists and engineers. There is an imbalance in the distribution of scientists in the field of agriculture. They are mostly employed in the general services sector and in the higher education sector; very few work in productive enterprises.

The survey of the enterprises, their employees and the institutions of training and research reveals that:

(i) The enterprises played a very important role in research and development. The firms increased substantially their investment in this area.

(ii) The average number of R&D personnel per firm has increased remarkably.

(iii) The dependence of enterprises on foreign R&D personnel has decreased to a large extent.

(iv) Constitution of R&D staff of enterprises is largest in the determination of products in the stage of strategy formulation.

(v) R&D activities of the enterprises are often self contained because of secrecy and competition.

(vi) Local firms co-operated more often with foreign firms than with the Korean multinational firms. The co-operation was mostly in transfer of technology. Firms with fewer highly qualified personnel co-operated more often with other firms for acquisition of knowledge.

(vii) Contribution of academic institutions in the area of research and development is limited because of resource limitations and their emphasis on basic research.

In respect of the development of higher education, one would observe the impact of laws promulgated for the promotion of science and technology on the increase in the number of four-year colleges, universities, the junior vocational colleges (JVC) and the high schools and in new courses. Enrolment increased by 10.6 times in high schools, 8.5 times in JVCs, 15.9 times in 4-year courses and 31.2 times in graduate schools during 1965-1975. During the period 1975-1984 enrolment growth slowed down in high schools but increased in JVCs, universities and graduate schools. Due to the very low base in the

graduate schools, enrolment growth rate appears to be highest here. These growth rates are much higher than the growth rates in the overall education system.

The contents and teaching methods at different levels of education are reviewed regularly. Computer education is carried out by several organizations during vacation time to compensate for shortage of trained teachers in term time. As regards vocational training, the technical high schools and public training institutions of the Ministry of Labour cannot satisfy the demands of companies for skilled labour. Large companies arrange their own training. The Korean Technical Qualification Testing Agency created in 1976 standardized the various lists of skills and registers the successful as holders of specific diplomas. The candidates generally come from the public training institutes of different ministries and the training programmes of companies. During 1975-1980 3.5 million candidates appeared on these lists and 763 thousand were successful. The importance of recurrent education is not yet very well appreciated by the enterprises and the facilities are not adequate for retraining. However the enterprises face the problem of identifying the skills that are becoming obsolete and those which are emerging. There is also lack of professional training of trainers in the field of recurrent education. Whatever enterprise training is available in Korea, it is organized mostly with university co-operation. However, the universities have the constraint of looking into the broader of goals of education which discourages, perhaps for the national benefit, too much specialisation.

The above findings provide us with some corrective measures for policy formulation for the education and training system at the national level, which will be discussed for 1) the formal system of education, 2) professional training, 3) recurrent education, 4) transition from education and training to work, and 5) industry-training institution relationships.

4.1. The formal system of education

In order to correct inconsistencies between the formal system of education in electronics and the needs of the economy, the content of the programme in electronics should be reorganized to emphasize computer related subjects including semi-conductor, creativity, new theories and

operation of equipment which can be applied in the industries. Emphasis should also be laid on seminar type of instructional methods. Practical work should be emphasized and apprenticeship training should be introduced. This would call for closer co-operation between schools and industry.

Efforts should be made to secure technical teachers in sufficient number who can combine theory with practice. One way to do so would be to introduce a course on information and communication in the curriculum of electronics and computer science so as to impart communication skills to students who may become teachers afterwards. Another way would be to make the academic criteria for recruitment more flexible so as to give credit for practical experience.

Since training in electronics is very expensive because of the equipment and its high rate of obsolescence, the school system should take advantage of industries which are better equipped. A levy could be imposed on industries for the education of their potential employees and thus could be used for equipping laboratories, and workshops with the necessary equipment including computer terminals. The universities should have more flexibility in the budgetary procedures so that the staff is motivated for carrying on research.

The schools could develop a network and pool their resources to equip their laboratories and could exchange the most competent technical teachers and instructors. Industries should be approached by schools to help them equip their laboratories under advantageous conditions. It is also necessary to organize refresher courses for teachers. Incentive measures should be adopted to attract good quality applicants for teaching and to reduce high turnover of teachers. Each school should have at least one teacher who has training in information processing or computer systems. Frequent visits by the students to industries manufacturing and using electronic products would also be beneficial. In addition, industries may be encouraged to hold exhibitions of electronic products, production processes, and their utilization, for the orientation of students. They should also be encouraged to take advantage of the human resources of the universities.

Some of the above measures would increase the unit cost of training, but some others, namely increased education-industry relationships, networking of schools and possibly the levy system would reduce the cost. It is, however, essential to reduce unit costs because of the limits of national financial resources.

4.2 Professional training

In this respect, there should be a more systematic effort on the part of the companies to increase training facilities. They should invest more in training, seek the co-operation of the formal system of education in respect of staffing, curriculum design, and design of instructional patterns and in the selection of potential candidates for training.

4.3. Recurrent education

The problems of recurrent education in the field of electronics have been outlined in Chapter V. In order to tackle the problems, the first task of the educational and industrial decision makers should be to apprise the owners of enterprises about the utility of recurrent education and the obsolescence of skills. The second task would be to arrange for training abroad -- in countries where innovations in electronics production and use of electronics equipment are taking place. Special emphasis has to be put on adapting such training abroad to local industrial capabilities and needs. The third suggestion would be to set up recurrent education programmes in the general universities and technical research and training institutes. The fourth task would be to organize crash programmes and short cycle training in the specific specialities. Finally, the modular system of training which is already in practice in some training institutes of Korea should be adopted for all institutions which will be organizing recurrent education in electronics.

The acceleration of development and innovations in microelectronics makes the promotion of recurrent education essential for the Republic of Korea.

4.4. Problems of transition from education and training to work

As for the relationship between employment and training, there are some points to be considered. First, the training institutions should identify the difficulties of trained students in adjusting to working life and take corrective measures to reduce these difficulties. Second, information on new skills and techniques should be provided continuously to trained students. Third, instructors should visit the companies to raise the morale of trained students. Fourth, they should encourage the companies to carry out more field trips.

As for the companies, first, they should discuss the right kind of training methods with the training institutions. Second, they should exchange information with training institutions on the skills needed in the field. Third, they should lend the equipment needed by the training institutions. Fourth, they should periodically review the incentives offered to employees. Fifth, they should likewise review the working conditions of the employees. Sixth, to stimulate innovation among the employees, they might introduce a proper reward system. With the adoption of these measures, employer/employee relationship would improve and the employees would have more responsibility for carrying out their work, more satisfaction, and their underlying abilities would be better utilized.

5. Government-Industry-Institution relationship

Interaction between the institutions of research and the enterprises is taking place in various ways in the Republic of Korea. Seminars and workshops are being held by universities to disseminate the latest technologies. The setting up of the "Science town" is one example of industry-academy co-operation. Joint research projects are also being conducted to a certain extent between the institutions and enterprises. Industry sponsored training programmes are being held at the universities. In the field of microelectronics, technological progress is so fast that it is not possible for any one agency to move alone. However, this co-operation has still large scope for improvement. In respect of content of curricula and equipment for practice, the following suggestions could be made at the macro level of our analysis. These are:

1. It is only by direct collaboration between industry and training institutions that content on analogue circuits and systems can be replaced by digital circuits and systems so as to keep pace with development in this area.

2. Training for the semiconductor direct circuit industry, the newest industry of the information age, requires that institutions should redirect the content of studies so as to emphasize the property of materials used in the semiconductor industry -- again calling for direct co-operation between industry and academic institutions.

3. Enterprises might loan equipment to those institutions organising telecommunications programmes which do not have adequate equipment in order to diversify their programmes.

4. Enterprises should help institutions by providing computers so as to promote computer simulation as a subject. This would achieve provision of the trinity of theory, test and simulation right from the start in training programmes.

The survey of the enterprises and employees and training institutions reveals a large number of inconsistencies in the relationship between government, industry and educational institutions. In respect of research, government fiscal and commercial policies have helped industries to develop their products whereas government research grants to universities have not brought significant technological breakthroughs. Training of R&D personnel also does not owe much to the universities. However in the pure training area universities and enterprises have done well according to the employees surveyed. Co-operation of institutes with enterprises has been more than significant[23]. Enterprises also co-operated satisfactorily with the R&D institutions for training. Sending students to firms for practical experience has also received a high score from the academic institutes. In the three selected areas of technological policy formulation namely, identification of technological trends, choice of products/production process and development of new technology co-operation is less than satisfactory. Co-operation in formulating a coherent employment policy for R&D personnel is also non existent.

23. Ibid., Chapter IX, Table 20.

According to the enterprises, consultancy and joint research projects, followed by hosting of seminars/workshops are the popular means of co-operation among the three agencies. For the universities, more financial support without strings from the government and industry is an important way to improve co-operation. Organic university-industry linkage in a community is another popular way of developing such co-operation as planned in the "Science town". They also suggest that industries should become involved in evaluating educational programmes.

The above suggestions provide some hints for policy formulation in organizing educational and training programmes in microelectronics in the Republic of Korea.

Case study No. 2

The role of the educational system in technological development of electronics/telecommunications in Indonesia

1. Introduction: the objectives of the study

The general objective of this research was to derive planning and policy implications for improving the education and training system in electronics for communication so that it can contribute to developing national scientific and technological capabilities. The specific objectives of the study were:

- to identify the role technological policies of the state and private industries have played in the development of the electronics industry for telecommunications;
- to identify the impact of technological development on employment qualifications and the career structure of the work force in electronics industries and communication services; and
- to examine the way the programmes of education, training and research in the country have responded to new needs for skills.

It was hoped that the findings would help in identifying elements for formulation of policies in education in general and in training and research in electronics in particular.

Methodology[24]

As in the case of the Republic of Korea, a macro approach giving the national scene has been combined with a micro approach where we have analysed the perceptions and experience of individual employees, enterprises and representatives of academic/training programmes in electronics/telecommunications in Indonesia.

24. For details of the research methodology, data needs and instruments for data collection, please see: Sanyal, B. and Moegiadi, IIEP Research Report No. 74, Paris 1989.

2. Principal findings and implications for planning

These will be discussed following the objectives set out above.

2.1. The role of technological policies of the state and private enterprises in the development of the electronics industry for telecommunications

The technological policy of the state is a part of state policy for overall development. The two most important policy instruments[25] for industrial development in the early 1980s were:

(i) the protection of domestic industry from foreign competition through tariffs, quantitative restrictions, outright ban on some imports, local content regulations and more recently, import licensing; and

(ii) the close regulation of business activity through a complex licensing system and the promotion of investment in government-designated priority sectors by recourse to a variety of tariff exemptions and other concessions granted by the Investment Co-ordinating Board.

The decree issued in 1982 followed by several others later, limited import of products including an import ban conferring absolute protection to television production, for example. Varying rates of tariffs have been imposed on "knocked-down" assembly kits of different products as well, depending upon the potential for local production.

However, more recently trade has been liberalised in Indonesia. The country is actively seeking foreign investments, has eliminated some of its import monopolies and allowed foreign investors into areas once reserved only for nationals. In June 1988, the government announced the following measures: (i) implementation of deregulation, (ii) implementation of bureaucratic reform policies aimed at decreasing red tape, (iii) minimization of existing differences between national and foreign enterprises and between urban and rural business, (iv) improvement of communication among private and public sectors on the one hand, and government administration on the other through formal

25. See Sanyal and Moegiadi, ibid., Chapter II.

and informal meetings. All these measures are directed at improving the industrial climate including that of the electronics/telecommunications industry.

The electronics industry for telecommunications is under the control of three departments: (1) Directorate General of Basic Metals and Industries for industrial electronics, (2) Directorate General of Multifarious Activities for consumer electronics, and (3) Directorate General of Post and Telegraph for telecommunications services. According to state policy, the electronics industry for telecommunication is considered as a strategic industry oriented by the Board of Strategic Industries set up in 1983 and considered important for support of national security and defence. In the initial stage, development of this industry was directed towards "multi-sourcing" and was supposed to phase out dependence on foreign firms or goods. It was also proposed to encourage training and research in electronics for telecommunication, as well as encourage self development of technologies and protection of such developments in the initial stages. However research and development has not been supported to a significant extent as yet. No incentives are given for investment in R&D in private firms, although state firms like LEN, PERUMTEL and PT INTI invest reasonable amounts in R&D. (According to one source 17 per cent of the PT INTI budget is allocated to R&D!) The state assists the industry indirectly to develop through use of control measures centred on import substitution, licensing and import taxes. It intervenes in the development strategy of the industry through 5-year plans, where the state enterprises play the major role in the production and consumption of the products and services and in the training and supply of manpower for the industry. Until recently the state applied extensive regulations to the development of this industry in order to protect the domestic market. The government has been active in control but passive in promotion of the industry so far. Although the country, at the initial stages proposed to phase out foreign dependence, it had to rely heavily on foreign technology because of lack of implementation of the policy on self development. At the government level, the Inter-university Centre for Electronics has been set up recently to pool resources for co-ordinated development of the industry. As mentioned before regarding general industrial development strategy, this policy for development of the electronics/telecommunications industry has also experienced a trend to liberalisation. Foreign enterprises are

being encouraged to establish "joint ventures" with nationals for the development of this industry. During the last decade, development of both electronics and telecommunications has been significant. However, the quarterly index of manufacturing production for communications equipment after achieving a three-and-a-half-fold rise between 1975 and 1983 went down to 2.43 in 1985[26]. The National Research Institute (LEN), in spite of slow progress, has produced a significant number of products. PT INTI, the public sector telecommunications enterprise, has also produced a significant number of products[27] in collaboration with foreign firms. Telecommunications services have also improved significantly during recent years. It is expected that 2.5 million telephones and 14,500 mobile telephones will be available in 1989 and digital technology will replace a large part of "analog" technology. PERUMTEL at present employs 40,000 persons and has an extensive network of training arrangements.

In respect of consumer electronic goods, a policy of gradual deletion of imported components has been encouraging progress in self development of television and radio, although this has been far less impressive than the rapid growth of production. At present the Directorate General of Multifarious Industries has stipulated the degree of local content as the main requirement for electronics companies to obtain licenses for further expansion and has formed a special team in charge of evaluating companies' performance in achieving the target local content of their products. However, local production costs are still higher than imported costs and there is lack of investment in establishing component-making plants.

In respect to computers, several local companies have been given a licence to manufacture micro-computers based on locally developed designs using imported components.

In the area of Research and Development, activities are limited to the state enterprises namely PT INTI, LEN and PERUMTEL. Private firms would like an independent laboratory for design and testing to compete with LEN, the state laboratory, the latter being also a producer

26. Ibid., Chapter III, Table III.7.

27. Ibid., Chapter III, p. 47.

for profit cannot serve the interests of the competing private sector. Also private sector enterprises do not like to share trade secrets through R&D institutions.

All three state telecommunication enterprises (PERUMTEL, INDOSAT and PT INTI) provide pre-service and in-service training and co-operate closely among themselves. Private firms arrange their training with their foreign principals. The Indonesian Telecommunications Association is of the opinion that specialised training in this area should be left with the enterprises because of its very specific nature. The formal educational institutions should provide the basic knowledge and instill problem-solving competencies.

The experience and perceptions of the enterprises, employees and academic institutions as analysed from the questionnaire surveys reinforce more or less the national phenomena described above. The large state producers have progressed in self development of products -- some of them from SKD (semi-knocked down) kits to CKD (complete knocked down) kits then to partial manufacture and finally to numerically controlled machines. The private sector has responded to the need for development by setting up new enterprises rather than developing new products in existing firms. In respect to bringing about technological change, the private firms indicate that they themselves are the main initiators, government and foreign companies play a less important role. The state firms, on the contrary, depend very much on the government to initiate new products or processes. The bottlenecks in introduction of new products are lack of skills, lack of local technology and government restrictions, according to the firms. Lack of inter-agency co-operation and existence of strict bureaucracy are cited by the state firms to be a serious bottleneck in innovation[28].

In respect to the means by which enterprises acquired technology, it was observed that self development was the principal vehicle. "Self development" in the Indonesian context means multi-sourcing of components and assembly of products. This is more common among private firms than public firms which used various methods from "turn-key" to "self development"[29]. The private firms conduct their

28. Ibid., Chapter VI.

29. Ibid., Table VI.3.

market research and feasibility studies themselves before launching a new product with little assistance from government and foreign companies. State firms receive co-operation from the Ministries. The state firms confirmed the important role they play in developing all aspects of electronics/telecommunications technology as discussed above, while private firms acknowledged their insignificant role in the overall development of this industry which was due mainly to too much state control.

According to state firms, employees and academic institutions, the latter, especially the state academic institutions, play a role in development of this industry by taking part in feasibility and market research, depackaging and adapting technology. The employees of producer firms played a significant role in developing new products by registering the largest number of patents. Small firms had been more active in this respect.

2.2. Implications for policy and planning of the electronics industry for telecommunications

The above findings allow us to draw certain implications for policy in the area of technological development in electronics. These are as follows:

1. The state should continue its support of the electronics/telecommunications industry as a strategic one and might provide specific incentives for its development in the form of

(i) tax exemptions for investment in research and development
(ii) consultancy services for private sector firms in acquisition, adaptation and production of technology
(iii) setting up research facilities and training for the private sector as provided by LEN and PERUMTEL for the state
(iv) providing information on available research facilities with which private firms could co-operate
(v) tax relief for export
(vi) liberalisation and deregulation of the economy
(vii) fiscal incentives and special credit lines to private firms for increasing the local content and development of new products.

2. The private firms may continue their efforts in
(i) multi-sourcing of technology
(ii) increasing dependence on national academic institutions
(iii) eliminating the mistrust of private firms towards academic institutions through a dialogue between the two parties and establishment of rational terms of co-operation which will benefit both parties. Such co-operation is in the larger interest of the country.
(iv) setting up a network of training and research programmes through the "Forum of Electrical and Electronic Associations" (APKABEL) and the Indonesian Telecommunication Association (APNATEL) while keeping close co-operation with academic institutions on the one hand and public sector enterprises on the other. SIEMENS may take the lead in this area since it has already a well developed training programme.

3. The impact of technological development on employment, qualifications and career structures of the work force in electronics industries and communication services

Development in the electronics/telecommunications industries has led to a corresponding increase in the scientific and technological potential of the country. The total number of personnel engaged in research and development in the whole country in all sectors nearly doubled in five years from 1979-1984[30]. The number of employed scientists and engineers increased by 20 per cent per year during the period 1982-1984. PERUMTEL estimates that its development will need an additional 15,000 people by 1994 and 80,000 people in 1999 (trebling the present size)!

The period covered by our survey i.e. 1980-1985 has seen significant changes in the staff size, qualifications, positions and functions of employees. All types of staff needed higher qualifications in 1985 than in 1980, although the private sector's needs were less. Sixteen per cent of the state enterprise staff in 1985 were graduates as against only 6 per cent in 1980.

30. Ibid., Table IV.5.

In respect of structure, the proportion of professional, technical and service staff has increased at the cost of clerical, production and managerial staff. Staff size has increased by 2.7 times in state enterprises as against 2.1 times in private firms during 1980-1985. The producer firms expanded at the slowest rate (1.9 times), while user firms (PERUMTEL and INDOSAT) increased their staff three times and computer firms by 2.05 times. The latter also increased their proportions of professional and technical staff. During this period, firms suffered a shortage of qualified staff in general but of R&D staff in particular. There has been a critical shortage in the field of digital systems, switching mechanisms, fibre-optics and telecommunications. Design engineers have also been in short supply in several firms in our survey. To remedy this situation, firms are sending trainees abroad and recruiting from abroad. Larger companies are inviting foreign experts to train Indonesians within the country. Crash training programmes are also being organised in order to upgrade existing staff. Recruitment of staff is carried out mainly by advertisements and in some cases by contacts with education/training institutions. Personal contacts play an important role with the private firms. The most widely used criterion for recruitment is performance in the "interview" followed by performance in an organised written test. Before administering the test or the interview preliminary selection is based mainly on academic and professional training results followed by "institution" attended especially for the R&D staff. Past performance was deemed important for sales and maintenance staff. Foreign language ability was important for design engineers, sales and maintenance staff. Private firms put more emphasis on "past" experience.

Job performance is the basic criterion for promotion for both types of firms. State firms give more emphasis to seniority while private firms emphasise professional competence. In respect to salary, the public sector firms of our survey pay more than the private sector (except for the computer firms). Even in the state sector salaries vary from firm to firm depending on their status. INDOSAT pays more than PT INTI which pays more than PERUMTEL which in its turn will pay more than a state university to "graduates" possessing the same nominal qualifications e.g. a university first degree.

During the period under study, employees improved upon their qualifications (56 per cent of the sample underwent further training in enterprises; 14 per cent state employees and 10 per cent private employees improved their formal education as well)[31].

Employees of state enterprises had more vertical mobility in their careers within the firm than those in private firms who changed employers to a public firm to obtain better career prospects. The main reason for change in the state enterprises is improved competence whereas in the private firms it was "change in the product", which may not necessarily lead to improved incentives. Change in function for some employees was from maintenance jobs to research and development and design. Two thirds of the sampled firms employed foreign staff to obtain the high level expertise necessary for development in the industry. However it was noted that private firms did not spread their recruitment nets wide enough, did not advertise sufficiently and did not establish contacts with educational institutions.

3.1. Implications for policy and planning

The above findings allow us to draw some additional implications for policy in the area of organisation of the employment market so as to respond properly to the needs of technological development in the industry. These are as follows:

(i) The segmentation of the industry in public and private sectors having two different technologies, market production structure and process, training structure and reward system may be eliminated through government policy by bringing them closer to the public sector with the help of an institutional framework. This will be elaborated later when the issue of government-education-industry linkage will be discussed.

(ii) The private sector should take advantage of existing facilities for recruiting its staff in a rational way and provide rational incentives to its employees so as to avoid the "hijacking" of bright graduates trained by the firms to other firms.

31. Ibid., Chapter VII.

(iii) They should mobilise their associations (APKABEL and APNATEL) to harmonise their terms of trade and overall functioning in the best interests of the country by establishing regular negotiations with relevant state authorities.

The above describes the impact of technological development in electronics for telecommunication on employment, qualifications and career structures of employees in the industry. The following section deals with the principal theme of our research: the way programmes of education, training and research developed in the country have responded to new needs for skills which will be followed by some hints for formulation of policies in education in general and in training and research in electronics for telecommunications in particular.

4. Response of the education, training and research system

The formal system of education, the enterprises own training programmes and the demand from individuals all responded in their own ways to the call for development of the electronics industry for telecommunication.

Courses for electronics and telecommunications were doubled in public universities and increased 2.5 times in private universities.

Most of the polytechnics offering these courses have been set up during the last few years. Enrolment in electronics in secondary technical schools also doubled during 1980-1985, as was the case with non-formal courses also. Applications for each place in these courses were on the increase every year. Cultural factors proved no impediment. Indonesians seemed to easily adapt to the challenge of the technological culture.

Teachers at all levels increased their qualifications on average during the period 1980-1985. Their number has also increased in most cases corresponding to the increase in enrolments.

A large proportion (34 per cent) of staff of state higher education institutes had Ph.Ds and M.Sc. degrees and most had been educated abroad. The private universities increased their staff only 1.6 times compared to an increase of 2.5 times in enrolments but they doubled the number of M.Sc. instructors. They also employ some staff with less than first degrees to assist the regular instructors.

The proportion of staff in polytechnics with a first degree rose from 21 per cent in 1980 to 39 per cent in 1985. At the secondary level, teaching staff increased only 20 per cent while enrolments doubled. However, the qualifications of teachers improved. Thirty-seven per cent of teachers held a first degree in 1985 as compared with 11 per cent in 1980. The proportion holding senior secondary level decreased substantially. For non-formal courses which operated mostly with part-time teachers, teaching staff tripled while enrolment doubled. A quarter of these staff held a university first degree in 1985 as against none at all in 1980. There was some mobility among the teaching staff of private universities who left to enter industries for economic gain.

An interesting feature of Indonesia is that graduates of non-formal courses and STMs find their jobs more easily than those of higher level institutions. This is because the lower level course organisers make greater efforts to establish links with industry to meet their manpower requirements.

Another feature of the Indonesian education system is its segmentation into public and private sectors reinforcing the phenomenon prevailing in the industrial sector. The universities and the state enterprises take the best graduates while private industry has to rely on unrecognised universities which nevertheless sometimes produce very good quality graduates. It has been observed that such good graduates when they exist cannot obtain work in the state sector because of their affiliation with unrecognised institutions. The public services, thus, remain deprived of their contribution. This definitely needs some corrective action which will be discussed later.

Training has been organised extensively in the enterprises -- both public and private either in the country or abroad -- in academic institutes or enterprises. This was mainly due to the fact that employees recruited before the electronic revolution of the late seventies and early eighties in Indonesia did not have any training in the subject and enterprises were obliged to retrain them in the field. Half of the employees received further training, the state, as usual, having a larger share than the private firms. Instructors, technicians and R&D staff of enterprises were trained in short term "training of trainers" courses by the state universities.

Enterprises like PERUMTEL offer updating courses for all levels of workers from unskilled (I-A type) to higher technicians (II-B) to promote them to the next higher level. The enterprise plans to train 2525 unskilled workers, 10,098 semi-skilled operators, 2119 skilled tradesmen and trade technicians, 991 higher technicians and 410 professionals during the period 1989-1994. The training content and methods vary from level to level. However, attitudinal training (in personality traits and affective skills) is given more emphasis than cognitive skill training. The training period varies from three months (professionals) to 18 months (higher technicians). PERUMTEL spends 2 per cent of its budget on training. Similar training programmes are also organised by PT INTI, LEN and INDOSAT, sometimes, in a co-ordinated way: one enterprise providing training for others in a specific programme. In the private sector, SIEMENS' training programme attracts trainees from both state and private firms.

In respect of research and development, private enterprises have very little to offer. Even in the public sector only 20 per cent of R&D staff hold a first degree and function at technician level. Most of the firms depend on their foreign principals for research and development. However, very recently state firms like PT INTI began spending heavily on research and development (17 per cent of their budget). State universities' electronic departments spent more of their budget in 1985 on R&D (40 per cent as against 17 per cent) than private universities. The state universities emphasised applied research and the private basic research. The former received their funds mainly from the state ministries, the latter from private trusts or enterprises. A number of higher education institutions exchanged staff with industry and a few have joint projects with industry.

The Inter-university Centre of excellence in Micro-electronics, set up in 1985, is now promoting programmes of study and research at graduate level. This centre, attached to a state university funded by a World Bank project, consists of a complex of equipment, materials, facilities and buildings, staffed by academic and technical experts belonging to related core disciplines. It provides research support, develops instructional material, assists degree and non-degree training programmes through offerings of courses, services, and internship for graduate students and faculty, it facilitates scholarly interaction among faculty and researchers from universities and research institutes

throughout the country and provides public service. The IUCs as a whole sent 147 staff in nine fields abroad for staff development during 1985-1987.

The above findings from our study provide us with some policy implications for the education sector which are discussed below.

4.1 Policy implications in the educational sector

As outlined above, a general policy for the development of the electronics/ telecommunications industry has been published -- this sector is in fact considered as one of the new strategic industries. Up until recently its development has been tightly controlled by company and import licensing regulations in an effort to stimulate indigenous substitution of parts and local innovation. However growth in the private sector has been erratic with little innovation due mainly to a low level of R&D activity and to its comparative isolation from government departments (who might offer assistance in feasibility studies and adaptation) and from research institutes and universities (who could help with R&D and training). State enterprises, on the other hand, expanded and adopted new technology, at the same time keeping close links with government departments and universities. Very recently (June 1988) the Government has taken steps to loosen control, some deregulation has occurred, joint ventures permitted and a desire to improve communications with private industry through formal and informal meetings has been voiced. However, no mechanism has yet been outlined. Since, industrial electronics are under the Director General of Basic Metals and Industries, services under the Director General of Post and Telecommunications, and consumer electronics under the Director General of Multifarious Activities, fragmentation will persist unless concrete steps are taken. (See Objectives 1 and 2 of the research study.)

Policy in the educational sector supported the expansion in the state enterprises by doubling course and student numbers and opening polytechnics to increase the supply of middle level technicians. As from 1985, universities began to perform a "training of trainers" role by giving short courses for instructors in industry. State universities have also given short term training for some R&D staff in industry, but the education sector has not yet been able to supply enough high level R&D and Design staff for which there will be an even greater demand in the

future. It will not be able to do this until it greatly increases its own R&D activities -- this concerns in particular the private universities who carry out mainly basic research at present (Objective 3).

It will have been noted that neither industrial nor educational policy have adequately covered the areas of R&D and university-industrial liaison and this despite the fact that the electronics/telecommunications industry is noted for its rapid rate of innovation, high use of R&D staff and its habit of establishing itself in clusters to reap the benefits of proximity to other enterprises (for subcontracting and transfer of expertise) and to training and research establishments. Repelita IV prescribed the establishment of a strong R&D capacity which was to be a combined effort, the government undertaking projects not carried out in the private sector. It seems that in practice the majority of R&D is done in state enterprises and universities. No concrete measures were taken to actively stimulate R&D in private industry and universities. Without official policies, R&D depends on individual initiative and as noted in the cases of the Republic of Korea and France, small-medium sized firms often do not have the resources to finance high level staff or to embark on innovation. Hence it has been general for the government to assist by R&D assistance and sub-contracting.

However, this section pertains to educational policy and it will suffice here to say that coordination of policies at national and local levels for industry and education will be necessary if industry and education are to reap the mutual benefits they desire[32]. For example, certain benefits conferred at national level (tax relief on R&D) can motivate enterprises to undertake initiatives at the local level requiring co-operation with research and training institutions, as could a channel of communication between small enterprises and relevant government departments so that the problems of small firms could be rapidly dealt with (i.e. they could be directed to expertise in the locality).

In the field of education, we have noted the particular problem of isolation of certain private educational institutions who in fact produce larger numbers of electronics graduates than the state institutions. They require assistance with curricula, more opportunities for applied research

32. Ibid., Table IX.5.

and for practical training of their students. Repelita IV requested industry to give practical experience and on-the-job training to students, but the offer has been insufficient.

Hence it would be useful if national policies could aim at:

- encouraging interaction of users, producers, trainers and researchers;
- interaction between basic and applied research;
- expanding the network along which information may flow to groups;
- providing measures to increase incentives to participate.

They may cover the specific domains of:

- Education-industry liaison
- Applied research in universities and polytechnics, particularly the role of private universities
- Public-private education liaison in the fields of curricula, training, research
- R&D and innovation in industry
- Private-public enterprise-government liaison

(Points 4 and 5 do not fall within the purview of this section but the opportunity will be taken here to stress two of the conclusions of our study -- private firms did not consider that they had a role to play in technological development of the electronics industry and state firms, as a corollary, found that the lack of local technology was the most important obstacle to progress[33].

Education-industry liaison

National policy might formalise education-industry liaison as a whole. In the state universities a beginning has been made by obtaining feedback on curricula, some training of trainers courses, funding of students by industry and practical training in industry, as well as a small amount of training of industrial researchers and research collaboration. However only two or three of the more advanced institutions in electronics are really active, whereas most of the country's research

33. Ibid., Chapter VI.

potential lies in higher educational institutions. Mechanisms might be set up to exploit this potential as far as possible, and without detriment to the other activities which must be performed.

In Indonesia, the electronics/telecommunications industry is concentrated in West Java so that it should be feasible to designate industrial and educational clusters, each member being informed that it falls within a certain cluster and being given the address of the contact point. In the scheme laid out in the study this would be the Industrial Liaison Centre to which enterprises could be invited to become associate members and certain of them participate in the Advisory Forum. It must be emphasised that the university should take the lead since so far industry has been loath to contact institutions of higher education, perhaps because they do not know whom to contact, have no resources to pay for expertise, and hesitate to share trade secrets. Polytechnics under the official policy are all to have Advisory Boards: the experience so far at IT Bandung polytechnic has been successful, but there is no reason why industry-education liaison should be confined to polytechnics only. Private universities with an Industrial Liaison Director could also undertake such a role but be associated with a state university or polytechnic so as to be able to benefit from assistance with curricula, loans of staff, etc. In view of the recent declaration of DJPT that it wishes to increase privatisation of higher education, it is important that expansion should go hand in hand with efforts to improve quality. It was noted that private education has been very flexible in expanding to meet social demand and that the growth of courses (formal and non-formal) has been most rapid in locations close to the telecommunications/electronics industry[34]. However, the theoretical nature of the courses in the private sector means that the output of graduates will have more problems in adjusting to the world of work. It will therefore be essential to draw the private sector into the network of industrial liaison: otherwise ever larger numbers of insufficiently trained graduates will come on to the market.

34. Ibid., Chapter V.

The secondary technical and non-formal courses might also be drawn into the network to try to ensure that supply of training is not duplicated in some areas while being non-existent in others and also to benefit from advice on curricula and from lectures and meetings organised by the Industrial Liaison Centre.

An institutional policy might be applied in universities covering resources for industrial liaison, objectives to be attained, procedures for staff consultancies and the confidentiality of work done for private companies. Amongst the objectives would be information collection, analysis and dissemination in regard to local needs for training and research. Such information would be fed back into curricula and be incorporated in newsletters giving details of training courses available by type of clientele and subject in the university, industry and non-formal institutions. Newsletters might also list the research being carried out in the university, proposed topics of final year students and invite collaboration.

In regard to information, one of the findings of this research was that data on output of electronics graduates and their utilisation does not exist at the national level i.e. Engineering graduates are not broken down by specialisation. Thus one of the tasks of the Industrial Liaison Centre would be to collect data for their region, covering number of students by level and speciality, repetition, drop-out, the number who continue in higher education to M.Sc. and Ph.D levels, and what type of employment graduates eventually take up. These numbers should be compared to stated needs in the locality, particularly for R&D and Design. It has already been noted that the enterprises employ graduates for different functions according to whether they are services, producers or computer firms i.e. computer firms employed comparatively more Ph.D and STM technicians whereas services need first degree graduates with some management education, and producers research and design staff and skilled technicians. Hence according to the firms in the area, needs will differ. Measures would have to be taken to encourage gifted students to enter areas of need. Such students could be sponsored by state industry and larger private firms which would help to alleviate the problem of repetition noted for Engineering students (a 4-year programme takes 6-8 years to complete). Sponsored students have less financial worries and are highly motivated to complete their studies when a sponsorship depends on it. The follow-up of graduates into employment would also

help to orient electronics specialists into occupations where their knowledge is useful (which was not the case for Engineering graduates). In this connection an effort must be made to ensure that private manufacturing industry is not being starved of graduates suitable for R&D work. The firms as a whole stated[35] that future staff will need higher educational qualifications than before. State industry or the government might even sponsor students to work in certain of the small supplier companies.

Applied research in universities

It has been observed that the state producers train their R&D staff in short courses at local universities, whereas private producers do not[36]. Only one third of the sample of private firms could be said to participate in the R&D network, most tend to try to train their own R&D staff in the firm (i.e. technicians have moved up to be R&D staff). Such personnel would benefit greatly from continual contact with university and other industrial researchers plus short regular training periods (small firms cannot afford longer). Thus university institutional policy would have to cover research collaboration with enterprises. The contract would have to cover sharing of intellectual property rights and the resources to be allocated by both parties. The university also needs to state its policy on innovations developed by its own staff members and how they might be exploited.

Research equipment for electronics is expensive and research collaboration contracts might also cover the loaning by industry to the university of equipment needed for specific research. In the case of private universities this would be particularly useful. Enterprises, for whom applied research is carried out could assign one of their staff to work part-time at the university and in turn receive the services of post-graduates for a time. In this way they will get to know potential recruits.

35. Ibid., Chapter VII.

36. Ibid., Chapter VIII.

The Government also might fund a number of appointments of post-graduates in industry for a certain period so that they could gain experience of both industrial work and business management and so that the cream of the graduate output will not be retained in higher education (i.e. it was noted that universities recruited their staff from amongst their own graduates).

As to resources for applied research, purely commercial funding would tend to lead to underproduction of research yielding general benefits, and a balance must be maintained, otherwise basic *industrial* research would tend to be neglected even if applicable to a wide range of firms. Thus industrial liaison centres/directors might conduct seminars to establish certain common problems of local basic industrial research which could be tackled in the university and pool funds donated by a number of firms for this purpose.

Information on the results could be spread not only through the group but published by the Inter-university Centre. It is particularly small companies who benefit from free diffusion and who are a prime vehicle for innovation[37] and one of the major tasks of the Industrial Liaison Director should be to obtain their active participation.

Finally it was felt by the participants in the sample surveys that the Government should take a more active role in the organisation of R&D in university and industry[38]. This could be done by the funding of staff for this work in the Inter-University Centre and Industrial Liaison Centres together with seed money for research.

Public-private education liaison

In part (1) above it has already been recommended that the private universities participate in the industrial-educational regional networks and some of the more advanced could be nominated as the main contact and organiser, the Government funding the Industrial Liaison Director (as it at present funds certain of the staff). National policy should make

37. A. I. Connor et al., "Academic-Industry Liaison in the UK: Economic Perspectives". In : Higher Education, Vol. 15, No. 5, 1986.

38. Ibid., Chapter IX.

it clear that the private educational sector is a partner in educational and national development. This was a specific request of the private institutions -- they would like a formal relationship to be established, including links with the government and private firms[39].

Public and private institutions should work together for the standardisation of all courses and qualifications in electronics/telecommunications in order to break up the present segmentation of the education and labour markets and promote the free flow of knowledge and human resources which is critical for the growth of the private industrial sector in Indonesia. This involves rapid growth of the policy of accreditation of private institutions.

It was suggested that for higher educational institutions as a whole there should be a mechanism for co-operation amongst all institutions majoring in telecommunications/electronics. In this respect, one of the first points of discussion might be the roles of the various institutions. It was noted that:

- Private universities concentrate on electronic theory in their courses and on basic research. In the future some of them would like to specialise (but on what should they specialise?).
- Polytechnics emphasise control systems in their courses.
- State universities give emphasis to telecommunications in their courses and expect their training to be at a general level. They carry out more applied than basic research.
- Non-formal courses wish to emphasise telecommunications in the future.

With these broad suggestions for policy formulation the research study came to its conclusion, having met its three specific objectives and tested the five working hypotheses formulated. In regard to the first, that secondary and higher training are influenced by technological policies, it is evident that since the electronics/telecommunications industry is led by the state enterprises, education and training has followed the dictates of this sector. Hence the policy suggestion above that the private sector should be able to make its needs known at the local level through the

39. Ibid., Chapter VIII.

Industrial Liaison Centre and to Government departments. Private industry has not so far been able to influence education and training apart from some feedback on the curricula.

The second hypothesis that any gap between the products of education and the needs of the economy was as much due to the inertia of technological policy as of educational was sustained. The gap exists in regard to high level R&D staff, Design Engineers and Applied Research which policies have overlooked.

The third hypothesis on the diversification of education and training as a result of the growth of the electronics/telecommunications industry was true for Indonesia though certain of the elements (training of trainers in universities) are of very recent origin. The fourth, linked to this, that resources are generated for training outside the educational budget, i.e. industry and individuals pay, was evident but little of these resources have become available to formal educational institutions, i.e. they have not helped to any extent to enrich the system by extra equipment and facilities: there are still grave shortages.

The final hypothesis that the role of educational planners in developing responsive educational programmes was limited in that they were only one of several groups of actors was underlined by the emphasis put on the need for coordinated educational and industrial policies in order to knit together the present segmented nature of education and industry in telecommunications/ electronics in Indonesia.

Case study No. 3

The development of scientific and technological research in the German Democratic Republic and its implications for training[25]

1. Objectives

The objectives of the study were (i) to identify the policy of the country in the application of science and technology in computer-aided information-processing; (ii) to examine the contribution of different educational institutions to the development of research workers for automatic data processing; (iii) to analyse the content and structure of training of university teachers in informatics; and (iv) to elaborate on the programme for the creation of research potential in the field of informatics.

2. The research methodology

This study has been principally based on a review of literature to look for answers to the questions generated from the specific objectives of the research mentioned above. Government policy documents, results of surveys undertaken for specific purposes and statistical yearbooks have been the principal sources of the data.

25. Wolter W. et al, IIEP Research Report No. 69, Paris, 1988

3. Principal findings and their policy implications

3.1. GDR policy in science and technology in computer-aided information processing

Among the achievements in science and technology of the second half of our century, computers are unparalleled in their effects on social developments. At present the development and application of microelectronics -- basic innovation for computers, computerization or electronization -- represents a main trend of the revolution in science and technology and the development of productive forces. The essence of this new phase in the development of productive forces consists in the transfer of international work processes and functions of mental work to technological means.

In the GDR, as elsewhere, the starting point is the recognition that this transfer requires specific means of work, namely software. This represents a new category of technological prerequisites, described in their sum total as information technologies. Software is at the same time an indispensable precondition of computer application as a whole.

Application of microelectronics therefore also means, above all, development and application of information technology, since progress in science and technology only becomes effective in productivity and efficient by way of technology and its achieved level. Furthermore, it largely depends on the efficiency standards of technology, how human labour can be saved and eased, and how it could become more productive and interesting.

Information technologies at present decide the level and speed of labour productivity and progress in science and technology in general, and they are therefore considered as key or high technologies. Whereas previously the steel consumption per capita of the population was considered the measure of the industrial standard of a country, today consumption in microelectronics has come to replace this criterion. It has been recognized throughout the world that at present no limits can be foreseen for the application of microelectronics.

Two factors merit particular attention in this connection:

- The role of information technologies in regard to the intensification of all parts of the reproduction process -- they penetrate all fields of human activity, they modify the content and

nature of work and training, they raise problems of the development of human personality in a new way, they condition new forms of scientific work organization and management, etc.

- The integration of information technologies in the other key technologies for their necessary control and management; the connection between bio- and information-technologies is thus regarded as an essential mark of the beginning of a new phase of the revolution in science and technology.

The objective requirements of the development of productive forces, together with the specific conditions of reproduction in the GDR -- caused, among other things, by restrictions arising from the long-term development of the population fit for work, and from the shortage of raw materials -- made it necessary to adopt a strategy of intensification of socialist national economic development. In 1966, the Council of Ministers and the leadership of the Socialist Unity Party held a joint conference, at which the basic problems of economic strategy were discussed, and measures were decided for their solution. In essence the transition to intensely expanded reproduction was decided.

There was also a disproportion between energy requirements and energy production; the development of the GDR during the past ten years shows that the removal of that disproportion without reduction of the rate of economic growth can be achieved. Energy-saving economic growth is ultimately based on the fact that less energy and more information is used per unit of industrial goods production. Information technology is proving to be a source of national economic growth, capable of reducing requirements in all other resources to a greater or lesser extent, without itself being replaceable by any alternative.

The factors briefly outlined above were and still are decisive in GDR policy in the field of informatics and information technology; in the following, the main phases of its development will be described. The results of that development are clearly shown, among other things, by the above-average high growth rates of the corresponding industries.

As a result of that policy the GDR is one of the few countries in the world which has at its disposal the necessary scientific and economic potential for the development, production and application of microelectronics. These great efforts were and remain investments for the future, they are requirements -- and results -- of the aspired to intelligence-intense economy, in which electrotechnics, electronics and

engineering decisively determine the industrial structure. Basically GDR economic policy starts out from the fact that modern products and production development in conformity with international market requirements today are inconceivable without the application of microelectronics and computers. Moreover, ambitious social targets cannot be implemented without an industrial basis in line with the possibilities of the GDR in the long term.

The development of electronic calculating technology as a means of intensification in the GDR stems from the co-operation of mathematicians at the College of Technology in Dresden (now the Technical University) with K. Zuse, who is internationally recognized as the pioneer of modern calculating technology; in 1941 he developed and constructed the first fully functioning (relais) automatic calculator in the world. As a result, in the GDR the first computers were produced as early as the first half of the fifties. During the sixties -- particularly in the second half -- essential national industrial capacities for the development and production of computer technologies were created (e.g. establishment of the industrial combines Robotron and Zentronik; development and production of the electronic calculator of the second generation R 300).

The decision in 1969 by the governments of the socialist countries to develop and produce electronic calculating technology jointly in the future was a decisive move. Two lines of development were decided:

- the Standard System of Electronic Calculating Technology - SSECT
- the System of Microcomputers - SMC

The merger of potentials of the socialist countries in the development and production of computer technology led to:

- The creation of a standard system through the participation of all countries providing the socialist States with a standard basis in calculating technology.
- The specialization of countries in particular items, allowing the concentration of development potentials and a more efficient production.
- The total potential of the countries involved in the development and production of calculating technology attained a dimension allowing long-term solutions of demanding problems.

- The alignment among the socialist countries in standards, development methodologies and management methods was promoted and the establishment of working co-operation between developers and producers also served to consolidate the amicable relations between the socialist countries.

Four years after this decision the first computers of the third generation were available as SSECT-Computers.

Recognition of the growing significance of automatic information processing or informatics led to the creation of hardware and software in 1969 -- to begin with at the Technical University in Dresden, and subsequently at other establishments of higher education. At the same time, specific training programmes in rudimentary informatics were developed and introduced in university courses for mathematicians, natural scientists, engineers and economists. These measures became part of the basic strategy of education, especially higher education, in the GDR, determined by the fact that in a country, the existence and prosperity of which mainly depend on the productivity of its inhabitants, education and training inevitably move to the front ranks of social values. Socialist industry as well is forced to rely on the initial and further training of its specialists, and therefore to be concerned about its development. This has been and still is of the utmost importance in connection with the application of information technology.

As in the development and production of hardware, there were at the same time agreements within the framework of the CMEA on the initial and further training of specialists. In this connection, training programmes for instruction in Management Information System (MIS) and/or Computer Aided Engineering (CAE) subjects were drawn up and introduced by joint teams of specialists. The term "MIS/CAE" defines the conditions of the comprehensive application of calculating technology and other means of automation for automatic information processing in management and control of production, constructive and technological preparation, etc. Around the middle of the seventies the development of microelectronics began. It is the basic innovation required for the large-scale application of computers.

Recognizing that this new technology is applied and managed by human labour, comprehensive targets were set for the corresponding initial and further training and some of the relevant concepts drawn up were immediately put into practice. During the period from 1983-1986,

these concepts led to differentiated programmes for public education, vocational training, and technical and higher education, and will be discussed in the following sections. In the field of higher education, complex courses of further training in "foundations and application of microelectronics" were introduced towards the end of the seventies for all university teachers and scientific staff members of universities and similar institutions. The objective of this measure was the long-term preparation and creation of potentials for a multiplication effect in the initial and further training of highly skilled specialists. This has today proved to be successful.

Furthermore, a number of centres of further training were set up at the universities and similar institutions, for example:

- microelectronics/informatics : Technical Universities of Dresden and Karl-Marx-Stadt;
- CAD/CAM[26] : Technical Universities of Dresden, Karl-Marx-Stadt, and Magdeburg.

This system was considerably augmented during the eighties and now nearly all establishments of higher education are comprised in it.

The many-sidedness of university and technical college graduates ensured by the system of education and training in the GDR was one of the main prerequisites for the necessary regrouping of specialists and their further specialization within the scope of further training courses. This is based on the extremely wide scope of the basic training in all disciplines. In this connection the basic training in informatics, introduced in nearly all disciplines at the beginning of the seventies should be mentioned. It was an essential precondition of the accomplishment of tasks, particularly in the field of the application of computer technology in all branches of the national economy of the GDR.

On the basis of quite considerable effort, essential technical and technological conditions were created during the years from 1980-1985 for computerization and electronization, i.e. the large-scale introduction of information technologies. This allows the GDR, together with the

26. Computer Assisted Design/Computer Assisted Manufacturing.

other socialist countries, to tackle the demanding task of the complex programme of advance in science and technology of the CMEA member countries up to the year 2000.

Up to the year 1990, the target envisaged is the accomplishment of the complex tasks of production and extensive introduction and application of computers of the fourth generation; they have the following quality marks:

- microelectronic maximum integration (LSI, VLSI);[27]
- proximity to the place of work, process integration;
- effective, convenient interface design computer;
- high differentiation degree in the processing range, construction principle, adaptability to uses, etc.;
- adaptability to inclusion in computer networks;
- efficient periphery.

In concrete terms, the XIth Party Congress of the Socialist Unity Party decided that up to the year 1990 the following should be produced and introduced.

- 85,000 - 90,000 CAD/CAM work stations;
- 160,000 - 170,000 office and personal computers;
- 1,900 - 1,950 minicomputers; and
- 660 - 670 electronic data processing installations (larger computers).

In this way the necessary measures in the fields of initial and further training assume new dimensions at all levels. The high standards of education of GDR workers, the numerous facilities for education and training and the clear statements on future demands offer favourable conditions for the achievement of this qualitatively new advance in the development of productive forces. It must be underlined that -- also according to international experiences -- the educational investments in connection with such programmes should not be under-estimated. Thus in Japan for instance, one-third of the investments in the national programme of computer development in the fifth generation are allocated to the corresponding training of specialists at all levels.

27. VLSI : Very large size integrated circuit.

3.2. The contribution of the different educational institutions to the development of the specific potential of research workers for automatic data processing

The progress of society, science and technology, the rate of which is decisively influenced by information technologies gives rise to new general scientific demands on specialists. These, as well as the specific professional demands arising from this work, must be taken into account in the training provided.

The development and application of electronic computer technology gave rise to a requirement for specialists with particular abilities to promote the further advance of technology, to ensure the effective utilization of the equipment, its operation and servicing and the preparation of specific professional problems for data processing. New branches of training had to be introduced at institutions of training for skilled specialists, technical college and university graduates in professions developed with the extended application of computers.

During the fifties and sixties, a comprehensive programme of data processing was launched. At the beginning there was a shortage of trained specialists in this field. All educational institutions endeavoured to close this gap by offering various forms of further education courses of lectures, post-graduate studies, etc.

A broad and solid basic training, particularly in mathematics and the natural sciences which even at that time were the main components at all levels of education, may be considered as good preparation in this direction. This encouraged skilled specialists, graduates of technical colleges and higher education establishments to make use of available facilities to improve their qualifications, with a view to preparing for work in the field of data processing. At the present time as well, the requirements in specialists for the development and application of modern computer technology in the GDR can only be provided for by an effective use of all capacities for initial and further training. This is the result of the rapid rate of qualitative changes in computer technology and the relevant scope for extensive applications.

This has confronted all experts employed in the national economy with the task of permanently continuing their education and training in the fields of the development and application of modern information

processing, with a view to the rationalization of their work. Further training in this field has acquired equal importance with initial training and education.

In the meantime, a wide range of further education facilities have been made available; they comprise basic courses in informatics or specific fields of informatics, and courses on the latest findings of research, which require preliminary knowledge and experience of professional work in informatics.

Some universities and similar institutions, such as the Technical Universities in Dresden and in Karl-Marx-Stadt, have developed into centres of further training in these subjects since the sixties. Furthermore a number of industrial combines, such as Robotron, provide training courses in aspects of informatics with a specifically practical orientation. The computer centres of the universities and similar institutions have made a specific contribution to ensuring the necessary unity of theoretical and practical education and training. Originally the computer centres had conducted the practical training of students at the computer within the framework of their courses of studies. At present the situation is changing, since the scientific departments of the institutes of higher education have opened computer laboratories during the eighties, which have largely taken over that function.

Co-operation between the institutes of the universities, the Academy of Sciences and the combines of the national economy is gaining in significance as regards the initial and further training in informatics and its various aspects of application of a high scientific standard and with an orientation towards practical requirements. Relations of a new quality are developing on the basis of contractual agreements, partly founded on long years of experience. Differentiated forms of co-operation are used to this effect, which provide favourable conditions also for the training of efficient research specialists for automatic data processing.

Programmes in informatics and the ability to handle computers were gradually introduced at all levels of education, from the polytechnical high school to vocational training courses, technical colleges and universities; these also comprise the necessary mathematical foundations. That process was intensified as from the beginning of the eighties. This is reflected, among other things, by the following changes:

- In the polytechnical high school the aim is to provide pupils with a general comprehension of informatics and elementary skills in handling computers. Thus the electronic pocket calculator was introduced as from the 7th class of instruction, and working groups for pupils interested in informatics and computer technology were created. At the special schools for mathematics and natural sciences, informatics have been introduced as a compulsory subject as from the 9th class, in which a programming language and the handling of computers are taught. Optional compulsory subjects are intended to consolidate the knowledge about the use of computers. At matriculation level computers are used in practical scientific work, and at present optional informatics instruction is being tested.
- A new curriculum has been introduced in vocational training during the years from 1986 to 1990. This envisages the training of all apprentices in the rudiments of automation in a compulsory subject of instruction, which is further consolidated in special courses for certain occupations. New vocational demands were taken into account by the modification of the system of classification of apprenticed trades. This also includes the elaboration of aims and contents of training for a number of new apprenticed trades.
- The training of engineers and economists at technical college and university level is restructured on the basis of professional work and requirements. Starting with the 1986 academic year, training in informatics is being tested in four directions. The objective of this training is the qualification of engineers for the development of basic and standard software. The training in informatics for the other engineering disciplines and for economists will be differentiated with an orientation for developers and one for users. These directions in training are being developed on the basis of international experiences and in co-ordination with the other socialist countries within the framework of the CMEA.

The elevation of the general training level in informatics, as a prerequisite of the ability to handle computers, is at the same time regarded as a prerequisite in the preparation of a potential of efficient research specialists. Great efforts in the training of the required teaching staff are necessary to guarantee a training in informatics at all levels of

education in the GDR. The facilities of the various educational institutions are being used to this effect. At present training colleges are preparing teachers in informatics for general and extended high schools, and there is a growing demand for such in all educational establishments. The formation of university teachers in informatics constitutes a focal point, since this creates the conditions for the training of highly skilled specialists capable of outstanding achievements in scientific research and the practical application of its findings.

The problems generally arising in the training of young scientific workers are particularly acute as regards informatics due to the fast rate of advance in this discipline. Considerable efforts are therefore necessary to meet the constantly increasing requirements for university teachers in this field.

3.3. Content and structure of the training of university teachers in informatics

Different professional requirements arise with the construction of computer centres at enterprises and institutions of the national economy. These are taken into account in training at various levels of education. Specialists for the operation and maintenance of computers were trained as from the beginning of the sixties. In the meantime, training courses for specialists in data processing of a high standard have been introduced for school-leavers of the 10th class. Such training may be followed up by a course of studies in informatics at the technical college in Gorlitz. Leavers of the extended high school may study informatics at a university or similar institution. Up to 1986, informatics could be studied at the Technical University in Dresden or the university-level College of Engineering in Dresden. As from the academic year 1986-1987 there were further training facilities in this subject at the universities in Rostock and Karl-Marx-Stadt and at the Technical University in Magdeburg.

At the beginning of the sixties, basic courses in data processing were introduced at technical colleges, in order to enable skilled specialists in various fields to make use of computers in their work. The demand for specialists of technical college standard with consolidated knowledge of mathematics and substantiated skills in utilizing information technology was evident at a very early stage. These

specialists were to be able to handle computers to the extent of assisting mathematicians and other graduate specialists in the effective application of computers. The training enabled them to carry out independent programming of certain aspects of problems and testing of a computer. In compliance with these objectives, technical assistants in mathematics were trained at several institutions of higher learning during the years from 1958-1978. The content of these training programmes proved successful. It represented a transitional form of training, because it took place at university institutions but did not lead to the completion of university education.

In 1969, training courses for data processing engineers (at the College of Engineering in Gorlitz) and for graduate engineers (at the Technical University in Dresden) were started through full-time and correspondence courses. The conditions for admission to a technical college was a completed vocational training in data processing. In accordance with practical requirements training courses at university level were also conducted in data processing, with a differentiated volume and content, in compliance with the different specializations for all disciplines.

Within the multilateral government commission for computer technology of the socialist countries, a council of specialists for initial and further training of MIS/CAE specialists, and international curricula for MIS/CAE specific fields of instruction, were created on the basis of an international specialist nomenclature. This largely corresponds to the existing nomenclatures of training in higher education of the socialist countries and is valid up to the present time. These specialists constitute the potential ensuring the advance of informatics in all its disciplines and the interdisciplinary solution of complex problems of application.

Four groups of specialists have been defined on the basis of the differentiated demands arising from the development and application of automatic information systems in the national economy. The different aims of training for these groups of specialists are determined by differences in volume and content of the MIS/CAE specific fields of instruction. Generally studies are sub-divided as follows:

- general education subjects,
- physics and mathematics,
- economics and organization,
- general technology subjects,

- MIS/CAE disciplines.

In accordance with the objectives of training, the following branches of studies were envisaged:

- Specialists for the development, production and maintenance of technology. The required specialists were and continue to be trained within the scope of the disciplines of electrical engineering. Examples are the disciplines "information technology and instrument technology" and "technical cybernetics and automation technology". The training enables students to develop electronic assembly groups, instruments and plants, and to produce, service and maintain them.
- Specialists for the development, adaptation and utilization of programmes, and for the analysis and synthesis of information systems; these specialists are trained within the scope of the discipline of informatics. In this connection it should be underlined that an equivalent training has been taking place for the past twenty years within the scope of the discipline of mathematics, in the subject "mathematical cybernetics/ computer technology". These specialists are mainly employed in the development and rational elaboration of operational and user software in all spheres of the national economy.
- Specialists for the economical, organizational and informational substantiation of automatic information systems; they are trained in subjects such as "mathematical methods of data processing in the economy". The aim of the training consists in enabling students to assist in preparing and implementing the rational use of electronic data processing for economic and operational tasks of management and planning, including production guidance and control.
- Specialists for the development and application of automatic information systems in all branches and areas of the national economy; for these tasks, specialists in information processing are trained, for example, in "information processing in building". The aim of the training consists in enabling the students to develop and effectively use specific software.

In addition, all students of the disciplines mathematics, natural sciences, economics and technological sciences are enabled, through a basic course of informatics, to utilize the computer technology available to them in the process of work as a tool. That basic training takes place within the scope of differentiated curricula for these disciplines.

3.4. Programme for the creation of a research potential in the field of informatics

On the basis of international and national analysis of the demands arising from the development and use of computers in all areas of social life -- elaborated by the scientific advisory council for informatics -- the GDR will start in the nineties with the following situation:

- 4 to 5 per cent of all employed will be specialists in informatics at various levels of education;
- 15 per cent of all employed will have knowledge and abilities in the field of informatics, varying in accordance to their specific occupations;
- about 50 per cent of all employed must be familiar with the latest information technologies to the extent of being able to use them as a matter of daily work routine.

These qualitatively new high demands were the basis for the transformation of the structure of initial and further training at all levels of education, in particular at technical college and university level. In general, this is now being gradually introduced.

The transformation of higher and technical education -- coupled with differentiated measures in the field of informatics -- is of outstanding importance, because higher and technical education:

- provides the specialists for training also at the other levels of education;
- higher education is the main basis of fundamental disciplinary and interdisciplinary further training -- including graduation -- and not least, because it plays a vital part in the creation of the potential of specialists for research and development in the field of informatics and all its areas of application.

The speed of the advance of informatics and its application is decisively influenced by the extent to which scientific preliminary conditions for the application of informatics can be provided, in

informatics and the respective special disciplines. That is why the specialists must above all be able to design information processes of the field of application or specialization, to create and further develop information systems.

A vital task of informatics specialists arises from the fact that according to international forecasts the costs of software in the automation projects envisaged for the nineties will make up a proportion of 80 to 90 per cent of the total expenditure. This means that laws, methods and means of work for the production of software will have to be found and applied, so that software technology must be developed as a specific branch of the discipline "informatics".

In planning the training of engineers and economists in the field of informatics it was envisaged that specialists for the development of basic and standard software should be trained within the scope of the subject "informatics", and those for software for more specific uses should be trained in the respective fields of application (e.g. "economic informatics").

Training programmes and skeleton plans of studies are available for informatics training in technical subjects, intended to guarantee a thoroughgoing and differentiated training process. A distinction is made between a user-oriented and a development-oriented training. All students of technological subjects must learn how to apply the means and methods of informatics in the practice of their specific subjects. Approximately 15 per cent of the students of a technological subject receive a more specialized training with the aim of being able to develop and introduce CAD/CAM solutions in their special branches and fields.

The specific profiles of the different universities and similar institutions and their relations with industrial combines are taken into account in this connection. Such relations and relevant agreements also form an important basis for long-term plans for the development of university teachers and graduate specialists.

A programme was developed for informatics training in the subject of economics, in accordance with the respective requirements, which is composed of the following four stages:

- thorough informatics training for all students;
- concentrated informatics training for approximately 15 per cent of the students;
- training in economics informatics;

- further training courses in informatics for economists.

In contrast to the mainly undifferentiated training of informatics specialists (engineers and graduate engineers for informatics) a sub-division into four subjects was introduced. These correspond with the distinct main fields of activities of informatics specialists. Accordingly, engineers are being trained, as from 1986, in the following fields:

- the further development of the theoretical foundations of informatics;
- the development of basic software;
- the development of information and control systems as a means of rationalization and automation of data processing;
- the planning and operation of computer systems and computer-based communications systems.

All four subjects comprise a general standard and a specific part, which is followed up by the specific part of the training in the respective discipline of study. Further specializations are envisaged in the scope of the disciplines, described as consolidating studies, depending on the research profile at the university or higher education institute in question. The whole training is envisaged as a course with a balanced proportion of theoretical foundations and practical skill. As in all other branches of studies, relevant vocational knowledge and practical experience are also required in informatics. This relates above all to the programming and use of computers. The preliminary knowledge and skills are acquired within the framework of preparation for studies. Varied periods of studies are envisaged for the training in each of the four directions up to qualification as an engineer.

In accordance with the requirements for developing a potential of adequately qualified specialists for the necessary informatics research and the systematic user-oriented research, capable students must be led up to graduation. Experience previously acquired in the organization of studies can be used in this connection.

The accomplishment of the demanding tasks to ensure the training of young scientific workers for the national economy, and for the Academy of Sciences and higher education institutions, calls for a systematic and differentiated training and further qualification of higher education teachers, in particular in the field of informatics, with its extremely fast rate of advancement. University teachers are ultimately

responsible for ensuring that the unity of learning and research, a thorough initial and further training, and the careful selection and training of specialists is guaranteed.

Case study No. 4

Science and technology in the educational system and technological change in the petrochemical industry in Algeria[28]

Summary of the main results

This study was organized around several themes that may be reviewed so as to summarize the main results.

1. Policies and technological change in the productive sector, based on the study of the petrochemical industry in Algeria

Algeria's policy for technology was strongly influenced by the model it chose for economic development, particularly in the area of industry. It aimed to establish a high-performance (independent) system of production capable of integrating various economic sectors, creating employment, and raising the level of productivity in both agriculture and industry.

Its policy for technology was thereby characterized by a massive influx from abroad of technology -- which the decision-makers wanted to be high tech -- for the purpose of narrowing the gap between the Algerian economy and that of industrialized countries while avoiding being saddled with a system of production that would rapidly fall into obsolescence.

The study of the petrochemical industry shows that this policy entailed a series of technological choices that in themselves led to a multitude of problems and challenges, but in essence involved the choice of partners, procurement contracts, modes of financing, pricing schemes, etc. These choices all required access to information and skills in the

28. Djeflat A., IIEP Research Report (in process of publication)

country capable of a high level of decision-making ability as well as management and organizational skills comparable to those found in developed countries, in view of the amount of investment carried out over a decade and a half, and the time constraints that the Government's determined efforts made yet more stringent, and the numerous objectives assigned simultaneously to Algerian enterprises.

All these factors forced decision-makers to turn to those models judged capable of achieving rapid sectorial development and which were possible under the easy financial conditions of the 1970s. These patterns included, in particular, importing integrated industrial units, first as turnkey projects and later as "product in hand", where all the major decisions were left to the foreign partners, relegating local personnel at that time to administrative follow-up. This also caused overwhelming reliance on foreign technical assistance, both to carry out the investments, for although local manpower had been hired and given on-the-job training, employees of even a relatively low level of skills were imported, and to conduct operations where technical assistance was supposed to pass on know-how as well as help run the industrial plants built. Although that technical assistance was dispensed with relatively rapidly in certain plants (Arzew), it persisted in other complexes due to problems of getting local skilled staff to take over.

This technology policy, being implicit in character, lacked any overriding strategic vision of national technological development. It pushed the issue of engineering and capital goods production into the background, as well as the need for Research and Development and technological innovation, despite a few laudable attempts which had relatively minor nationwide impact.

2. The role of the petrochemical sector in training to meet the demands of technological change

The petrochemical industry is one of the key sectors for development since it provides the basis to develop other parts of the economy and has multifarious links with agriculture and other industrial sectors downstream. The petrochemical industry in Algeria imported its methanol and plastics plants as integrated complexes as a way of solving

the many problems that confronted them. Decision-making power was hence given to suppliers, who were called upon to carry out total assembly or act as equipment subcontractors.

This procedure was part of the oil industry's overall approach, which for nearly two decades was totally controlled by a single enterprise: SONATRACH. Owing to the huge contribution oil was making to the nation's balance of payments and hence to the economy in general, this firm was able to impose its sectorial approach to problems at the expense of any alternative global planned approach. This explains in part why large scale independent training schemes were devised to cope with the need for skills induced by the massive importing of technology.

These schemes consisted, in particular, of creating an autonomous training system using in-house production-oriented programmes run within plants, as illustrated by the two petro-chemical complexes examined in this study, and of establishing a sectorial training system comprised of educational institutions designed exclusively to serve the oil industry, especially the Algerian Oil Institute (IAP) and the National Oil and Chemical Institute (INHC).

3. The role of the petrochemical industry in the Algerianization of cadres

The autonomous training system set up in this manner made it possible to produce people with the skills required to operate the plants built, and more generally, to strengthen the nation's technological potential. Furthermore, it made it possible to Algerianize the managerial staff. Although these results were appreciable in some instances, e.g., the complete replacement of the foreign technical support staff by locals at the Arzew resin and methanol complex, and production exceeded the designed capacity in the methanol unit, in other cases this approach to training proved disappointing since operations continued to require the presence of technical assistance personnel (e.g., at the plastics plant at Skikda) and the Skikda and resin units were utilized to 50 per cent or less of capacity. This points to problems in the training system as well as in the way the production facilities were used.

Two further observations need to be made:

• First of all, although this autonomous training system made it possible to take over operation of production plants more or less successfully, it did not always foster the development of those skills which would permit technological changes to continue to occur in the post-investment period (technological reproduction and adaptation), particularly in terms of R&D and technological innovation which, not withstanding a few positive experiments (e.g., resins in the Arzew complex), lacked a systematic, global approach to the issue of technological development. Hence people with the special profiles required for the technical support and R&D functions were woefully lacking, e.g. technical documentalists, and neither the national educational system nor the specific training system for this sector of production took the trouble to produce such people. Furthermore, owing to the serious lack of scientific and technical documentation, technical professional staff are not abreast of recent technological developments in their field, and they have no possibility of influencing the technological processes they use.

• Secondly, this sectorial training system is almost completely independent from the country's mainstream educational system, particularly in higher education, despite the fact that it recruits people who have been through the technical and general secondary schools as well the vocational schools as candidates for enrolment in its own training schemes.

Both the phenomena just described may be attributed at least in part to the kinds of contractual arrangements made to acquire technology. Because the power to make major decisions was de facto with the foreign partners engaged in "product in hand" projects, local industries found themselves marginalized and virtually excluded from the training system while research and development activities were controlled by the technology suppliers.

4. How the educational system responded to the productive sector's need for skills: the scientific and technical option

The national education system realized early on the importance of setting up scientific and technical options to meet the needs of the productive sector and provide it with the cadres required for it to function properly. Several reforms were implemented for that purpose,

including in the primary schools (introduction of polytechnical education in the third cycle of the basic school), in the secondary schools (establishment of technicums, CEMPs[29] and FPSs,[30] even if that was done at the expense of the CETs[31] which were a relatively successful inheritance from the colonial era), in the vocational schools (establishment of new centres, preparation of the law on apprenticeships, increase in enrolment), in higher education (the Reform of 1971, increase in enrolments in science and technology by means of several procedures, starting local post-graduate programmes and sending students abroad for specialized training), and last but not least, in research (establishment of a national agency for scientific research with research centres in various specialties, creation of a senior body for research and a national plan for scientific and technical research, and subsequently the expansion of research to include those working in industry).

If the system of production was able to operate and find people ready to receive more specific training in various fields of science and technology as well as management, it was thanks to the education system which had provided them with a basic educational grounding at all levels -- at the primary school level unquestionably, at the secondary level, especially as concerns technical education, at the level of higher education for managers and technical cadres for the petrochemical industry, and at the vocational school level for the lower-level skills required by skilled and specialised workers, foremen and technicians.

Despite such efforts, the result may be considered to be below what really might have been possible. This may be attributed to a certain number of difficulties encountered in offering scientific and technical options of study within the educational system. In the secondary schools, the technical option stagnated because technical subjects had a lower social status compared to general education, as well as being hampered by a dearth of staff and equipment. In vocational schools, the gap in social status is even wider, the number of graduates has been inadequate, and curricula have continued to be largely theoretical and

29. Middle Technical Schools.

30. Vocational Training.

31. Technical Education Colleges.

poorly matched to the needs of the productive sector of the economy. In higher education, any science and technology major still involves taking courses that emphasize theoretical matters and rely on syllabi imported from abroad without being adapted to the conditions prevailing locally. Course offerings are geared much more towards obtaining diplomas than to equipping graduates with skills demanded by the productive sector for training and research.

As regards the importance of research, this depends on the kind of activity. R&D has a major role in the petrochemical industry for both the chemical processes and the equipment and special materials they require. Although there were a few successful experiments with technological change, e.g., in resins, there have been far too few improvements made in the original equipment. Even the maintenance of some equipment, for instance, the autoclaves, has caused major problems at times. Thus the R&D function as regards hardware has to be taken properly in hand.

5. The relationship between the educational system and the productive sector, and their disfunctions for the petrochemical industry

The case study of the petrochemical study has shown that breakdowns in the relationship between the educational system and the productive sector occurred in several forms, ranging in severity from the total absence of any relationship to the existence of formal, sporadic, short-lived liaisons, semi-formal individual linkages, and quite informal contacts.

Several factors, both objective and subjective in nature, help to explain these breakdowns. Among the objective factors, special mention may be made of the lack of organizational and institutional structures, the high turnover rate among officials at one point in time such that no continuous approach was followed, difficulties in adjusting the educational system to what was needed, particularly by means of curriculum development and appropriate courses, excessive reliance on integrated types of contracts such as turnkey and "product in hand" for importing technology, and last but not least, the absence of any global strategic vision of technological development for the productive sector and scientific and technical courses of study within the formal educational system.

Among the subjective factors, one may include negative and prejudiced perceptions of the educational system on the part of the productive sector, and negative perceptions and prejudices on the part of the educational system towards the productive sector, and more generally, a failure on each one's part to have trust in the abilities of the other. Admittedly, some of these prejudices and apprehensions had good basis in fact. One example which may be given was the way some university professors conducted research on theoretical topics totally divorced from the reality and daily concerns of their country, and similarly, in the productive sector, the phenomenon of people managing to obtain jobs for which they had neither the requisite qualifications nor background.

6. Implications for educational planning, especially for scientific and technical courses of study

There has been relatively limited experience of educational planning in Algeria in the past for a combination of several reasons. Economic planning in general was weak which may be linked to the period of the 1970s and early 1980s when the labour market was in a state of relative euphoria so that any graduate of the educational system could easily find a job. The situation changed in the mid 1980s, when oil revenue plummeted and joblessness among graduates soared. Government authorities were thereby led to attempt to control school enrolment and introduce a university school-mapping procedure to plan and control enrolment figures for the entire country and channel students into particular courses of study. This introduction of education planning has encountered a great deal of social resistance inasmuch as it runs counter to ingrained habits. Public opinion nationwide has been polarized around the issue of limiting the number of students allowed to enrol, and has overlooked all other aspects of the problem.

The task of planning scientific and technical education has proved to be a difficult one, not only on account of the disfunctions mentioned above but also because of specific features of the educational system, the productive sector and the relationship between the two.

As regards the educational system, scientific and technical courses of study suffered from the shortcomings in technical education in the secondary schools, where a real bottleneck occurred. The students were of relatively poor quality, and there was a shortage of opportunities for transition from one cycle to another in higher education.

As regards the productive sector, difficulties in formulating needs arising from imported technology and the resulting problems in defining the functions to be targeted for educational planning, the autonomous decision-making habits of enterprises in the area of development and policy formation, and the lack of coordination between enterprise plans and scientific and technical development plans all contributed to making it hard to plan scientific and technical streams of study.

As regards the relationship between the educational system and the productive sector, the absence of co-operation and coordination between institutions at the ministerial level, the lack of coordinated timing between actions undertaken by the world of education and efforts made in the area of training, the inadequate relevance of curricula, and the issue of Arabization -- not as a dogma but with respect to the matter of technological change within the productive sector -- all constituted barriers to planning for scientific and technical courses of study.

Finally, one should mention the process of marginalization of science and technology, and the importance of scientific and technical planning such that the instruments of planning themselves lagged behind the demands of the world's scientific and technological evolution. This issue must be understood in the context of social dynamics which for a long time tended to degrade the status of science and technology and knowledge in general.

7. Parameters for new dynamics between the educational system and technological change in the productive sector

The relationship between scientific and technical education and technical change is being altered by new dynamics between the educational system and the productive sector. The cause of this new situation is, paradoxically enough, the crisis Algeria has been experiencing as a result of a drop in its oil revenue, or as a result of what may be called the worldwide economic crisis, which limits opportunities for seeking help in world markets and encourages the country to search

for domestically-based solutions, including by turning to an educational system endowed with far greater potential at present than it had when the process of industrialization first began. These dynamics are enhanced by the new political context of greater openness and economic and social reforms, including a thorough reform of the educational system, particularly the universities, to bring the educational system into closer contact with the productive sector.

The prospects for increasing technological change in the petrochemical industry worldwide point to greater reliance on traditional basic commodities (gas, oil) and the emergence of new technologies upstream. These global developments hold out interesting prospects for developing countries, which may hope to play a greater role in the process of creating and disseminating technology, especially by means of concerted regional and sub-regional action and alliances. The consequence of this will be a need to develop skilled personnel capable not only of making optimum use of technology in an autonomous manner but also of participating more and more fully in the process of generating new technology. Algeria cannot escape from these worldwide developments, especially since its internal and external constraints give it greater impetus to develop its productive sector yet further by increasing existing capacity, diversifying output and integrating production both upstream and downstream. In terms of technology, this means using scientific and technical knowhow and ever more sophisticated equipment. Consequently, it will have to train highly skilled people, and especially rapidly expand the nation's abilities to perform Research and Development.

For scientific and technical courses of study within the educational system, future proposals include concrete action to strengthen this stream of education by means of several governmental measures, including: the establishment of a National Commission for Reform of the Educational System (June 1989) to give better management of scientific and technical education and rehabilitate vocational training, and to grant a large budget appropriation (47 per cent of the overall budget for the educational system in 1989).

Although the prospects are favourable for achieving greater co-operation and more dynamic action between scientific and technical courses of study in the educational system and technological change in the productive sector, a certain number of conditions must nevertheless

be satisfied before that action can be fulfilled and not be hampered in their implementation. These conditions include redesign of curricula and courses (to be revised completely with the active participation of people from the productive sector), the establishment of institutional mechanisms (interministerial commissions, university mapping, incentives for individual initiatives undertaken in the framework of the autonomy granted to the enterprises and the independence to be given in the future to the university system), and the elimination in both sectors of those prejudices which have maintained and widened the gap between the two entities for so many years.

8. Implications for policy-making and future planning of the educational system

The implications of such future developments for educational planning may be listed as follows:

1. A need to reformulate the notion of planning by an enrichment of the techniques it uses for information-gathering, forecasting and implementation.
2. A need to deepen and broaden the educational activities linked to technological development.
3. An end to sectorial planning of education and training, as was practised by the large enterprises. The restructuration of enterprises into small-size units is likely to lead to yet further atomization of the decision-making and policy-making processes.
4. A need to foster inter-sectorial action in the field of educational planning, including for general education, vocational training, higher education, scientific research and the productive sector. This approach is particularly important in the case of Algeria since the rules of a market economy are becoming more prevalent in the country's approach to economic development (cf. the new Government's programme announced in September 1989) and since the Ministry of Planning has been eliminated and replaced by a National Planning Commission in charge of the main aspects of the economy. The current belief in the virtues of a market economy to solve all ills should be reflected by taking account of the specific demands of scientific and technological

development, given that this is a developing country and any attempt to transpose the experience of developed nations must be done very cautiously.

5. If one accepts that a global, integrated, multi-sectorial approach with coordination at the top levels of authority is necessary in order to engage in educational planning consistent with and appropriate to the demands for future technological change coming from the productive sector, it is important to assess carefully what this approach will require in terms of information, the importance of which has already been underscored, as well as skills in organization, management and coordination. Such skills must be put to careful use. That means that the National Office of Statistics, which at the present time is the only agency collecting and processing statistical data, should have its scope of responsibilities increased and its activities diversified so as to be able to deal with data about scientific and technical courses of study and technological change, working in conjunction with the National Centre for Technological Transfer whose performance is still below what is actually required.

6. Finally, in view of the imperfections of tools for educational planning, which have led to neglect of the issue of technological change, it will be necessary in future to integrate an analysis of the prospects for technology in the field of petrochemicals and all other sectors (given the close relations between this key industry and the others) into a general review of manpower forecasts and skill requirements. This will necessitate undertaking a nationwide process of reflection and research on planning of scientific and technical educational streams within the formal educational system as well as technological change in the productive sector, so as to help improve planning techniques to make them more appropriate to the situation in Algeria and contribute to work in this field at the international level.

Case study No. 5

Development of the oil industry in the Cameroon and its implications for education and training[32]

1. Introduction: Principal findings and implications for the educational and training system

The objective of this research was to analyse the influence of the development of the oil industry in Cameroon on the expansion, structure and content of the country's formal and non-formal education and training system. The study, in the process, attempted to analyse (i) the industrial and technological policies of the oil industry, (ii) the impact of these policies on the economy and employment structure of the workforce, (iii) the impact of these developments on training and educational needs, and finally the objective was to derive implications of these developments for planning of education and training in the country so as to meet the needs of the oil industry.

We shall discuss the results of the analysis and their implications for educational planning below.

2. The economic framework of the country and the evolution of technological policies

The Cameroon, in common with all developing countries, has experienced the vicissitudes of a young nation state after independence. The country began on a high note with a development strategy of planned liberalism, self-reliance, balanced development and social justice. At that time, most of the private enterprises were owned and operated by foreign nationals so that the appropriate role for the state was seen as creating a favourable infrastructure and public utilities while

32. Sanyal, B.C., Ndongko, W.A., Varghese, N.V., Ngu, J.N., and Inack Inack, S.: IIEP Research Report No.79.

encouraging Cameroonians to develop the private sector. In the 1960s, Cameroon benefitted from a favourable world economic climate and had a surplus to invest. It continued to attract foreign capital but at the same time encouraged private initiatives by an investment code and a protected domestic market.

A trough in the country's fortunes occurred in the 1970s; public enterprises were less profitable, private investment stagnated, world terms of trade turned against primary products. In response, the Government changed its industrial policy in the early 1970s to reduce reliance on foreign investment and gave even more encouragement to national initiatives for economic development, but this had to be financed out of treasury reserves. This still failed to generate sufficient employment and train enough local manpower. Thus the late 1970s was a period of deficit financing, increasing unemployment and a general slowing down of the economy.

At that time, oil came on stream, the revenue from which permitted expansion of manufacturing (in particular aluminium and fertilisers) and construction. Assistance was given to small and medium enterprises while diversification and dispersal of industry was encouraged by preferential treatment. By the mid-1980s, the Cameroon had made some progress towards industrialisation; traditional agricultural exports had fallen to 58% of the total while industrial product exports had risen to 20%. The urban population increased to 40% of the whole.

Thus exploitation of oil was a turning point in the economic development of the Cameroon: it provided the resources to give impetus to a stagnating economy. However at the same time certain reserves were put aside to try to avert the onset of "Dutch disease", i.e. usually when oil revenues are spent domestically, the real exchange rate appreciates leading to a shift in the production mix to non-tradables. In the Cameroon, this occurred in the aggregate but some tradable sectors expanded, in particular the import-substituting industries underwent an increase in demand. However, efforts to protect tradable sectors with tariffs had little effect on reversing the structural change induced by oil revenues.[33] Revenue was spent not only on investment and settling of

33. Benjamin, N. and Devarajan, S., "Oil Revenues and Economic Policy in the Cameroon", World Bank Staff Working Paper No. 745, August 1985.

debts but also on increasing the number of civil servants and para-statals, which made it very difficult to adjust to the decline in oil receipts which occurred in 1986 due to falling oil prices and the depreciating dollar.

The most recent Five Year Plan (the Sixth: 1986-91) attempts to develop a Master Plan for Industrialisation to serve as a framework for encouraging the private sector and continue the process of Cameroonisation. The Plan considers oil as one of the strategic industries and includes extension of the refinery, exploitation of natural gas and manufacture of raw materials for plastics by the year 2000.

In respect of the evolution of the technological policies of the oil industry the following findings were noteworthy.

Given the extent of foreign capital and manpower in the industry and mining sector in the Cameroon, development policies from the first took into account the need to continue reliance on foreign expertise while encouraging Cameroonisation. As time passed, the role of the state in regulating foreign intervention increased, but while the policy of self-reliant development was successful in the agricultural sector, this was not generally the case in industry. Thus the Third Plan (1970s) created technical and financial structures to assist local small and medium enterprises and only then did the share of foreign investment start to decline.

Efforts to plan technological development are recent. After several false starts since independence, in establishing national research organisations, the National Committee for the Transfer of Technology (CNTT) was set up in 1978. It has wide and challenging responsibilities, including cataloging national needs in the realms of science, technology and industry; studying modalities for the transfer, adaptation and use of technology and selecting foreign technology that would contribute efficiently to Cameroon's development. However, even the Cameroon National Union (CNU) Congress held at Bafoussam in 1980, which was dubbed as the "Congress of the Mastery of our Development" made no reference to the urgency of developing an institute to cater for technological development. The government did register its resolve in the Fifth Five-Year Development Plan to set up a Technological and Industrial Research Institute, but this is still awaited.

On the education and training side, very general official statements have been made concerning the provision of technical education (see Fifth and Sixth Plans) and attempts by the Ministry of Plan and Regional

Development to compile an inventory of national technical skills as well as various scattered international efforts to study university-level manpower supply and demand in Cameroon have met with little success (Sack et al., ibid., 1986).

The oil industry was of little significance until 1980 but by that time the state had clearly defined policies for the exploitation of its natural resources i.e. a strict system of licensing under which the state received the majority share of output, the proportion increasing as production increased. In addition, it took the refining and petrochemical industries under its control. However, exploration and production of crude were left mainly in the hands of the multinationals. The problem here was the uncertainty concerning the existence of viable reserves. Sources of crude may be exhausted by 1994 or on the other hand, new reserves may be found. The same uncertainty surrounds gas reserves.

Thus technological policy was concentrated on the practical aspects of setting up and training enough manpower for the production and maintenance activities of the refinery. The time scale (1980-86) is still so short that policy-making has not been brought to bear on R&D for new production processes or new products etc. Thus this report will appear at a time when it can make a contribution to the discussions and plans of CNTT over the next few years.

This is important since the country's new "Master Plan for Industrialisation" is now being finalised, the oil industry being included as one of the strategic industries whose development is mapped out up to the year 2000 together with manpower needs. The plan still assumes a strong dependence on foreign technology and no mention is made of projects to include the oil sector in the R&D and teaching programmes of higher education.

The above findings allow us to draw certain implications for policy in the area of technological development in the oil industry within the broad framework of the economic development strategy of the country. These are as follows:

(1) The tax conditions governing oil exploration which are currently less favourable to the exploring companies should be revised so as to motivate these companies to invest in exploring new resources, by adopting new and sophisticated technology, if necessary.

(2) The combined effect of the decreases in oil volume and prices will reduce Cameroon's gross domestic income. This calls for serious attention to be given to the "Master Plan for Industrialisation". This strategy in addition to emphasizing diversification of industrial investment also recommends diversification of investment in the oil industry by exploration of natural gas, investment in the petrochemical industry and expansion of the oil refinery.

(3) The country should give more attention to the development of local technological capability not only for the oil industry but as an overall development strategy. This would call for more effective co-operation with foreign companies to start with under a national policy for transfer of technology. This would also require an institutional infrastructure for research and development. There is an urgent need for setting up the Technological and Industrial Research Institute which was proposed in the last five-year plan but has not yet been implemented.

(4) The foreign firms should be considered as a rich resource for development and should be encouraged to help the country expand its industrial infrastructure. A framework of co-operation should be developed between them and the country which will benefit both sides in the long run. Their active participation should be sought throughout all the stages of the development strategy -- from formulating the policy to implementation of programmes. This co-operation will call for sophisticated negotiating skill on the part of the Cameroonians which will ultimately have to be imparted by the education and training system and will be discussed later.

(5) Keeping in view the "Master Plan of Industrialisation", of which oil is an important item, attention should be given to amassing data on the stock and flow of highly qualified manpower. No analytical human resource development study has yet been undertaken by the country. This is an essential step for successful implementation of any development strategy.

3. The impact of the oil industry on the economy and employment

Oil was found off-shore in viable quantities in the south west region only, though exploration is still going on in the north. Production was estimated to have doubled between 1982 and 1984, reached its peak in 1985 at 8.85 million tons and then fell to 8.28 million tons in 1987.

Known reserves will be exhausted in the early 1990s unless further sites are found. However, there are extensive gas deposits in the Littoral region.

The state refinery, which began operations in 1981 can now satisfy the needs of the country for light petroleum products.

The impact of oil on the Cameroon's export earnings was rapidly felt: from 1.4% in 1977/78 oil exports rose to 67.8% in 1983/84 falling back slightly to 65.4% in 1985/86.

The direct impact of the oil sector on employment has been small -- about 3000 jobs (0.5% of secondary sector employment) in 1986. However these jobs are highly significant for the country's technological development since practically all of them -- foreign and national enterprises alike -- entail a major and costly training investment and the employees are amongst the skilled élite of the country.

Indirectly, it was estimated that due to oil revenues, 20,000 new jobs have been generated annually in the private and para-public sectors in addition to 8000 per year in the public sector. Such employment was created by major construction projects like docks, airports and dams as well as by the creation of a network of rural health clinics. If the draft Master Plan for Industrialisation is approved and implemented the country's demand for high level manpower in the oil and related industries will increase. According to one estimate, the extension of the refinery will need 550 skilled staff including 80 engineers, the natural gas complex will need 400 staff (60 p.c. professional), excluding 211 man months of expatriate staff, the complex to transform natural gas into ammonia/urea and methanol will need 736 staff excluding 26 expatriates and the plastic factory will need 117 national professionals and technicians and four expatriates by the year 2000.

Implications of the above findings for planning are as follows:

(1) The declining role of the oil industry in the economy and on employment creation calls for the decision-makers to diversify the economic activities of the country and to look for new reserves. For this qualified human resources are essential. Education and training needs to be geared to develop such manpower so as to explore the natural resources of the country, to exploit them for economic well being and to distribute and manage them. The education and training system should be able to impart the relevant skills and be production oriented and employment related.

(2) For the country to implement the Master Plan for Industrialisation and have the oil industry play its role properly it is necessary to train the required manpower envisaged in the plan. This would call for:

(i) Joint action by the government, industry and the education sector in developing the content, structure and method of instruction.

(ii) Establishment of co-operation on national terms with foreign firms, so that the activities of exploration and exploitation and distribution of the oil and related resources can be carried on smoothly.

4. The education and training system for the oil industry

The oil industry selects its skilled and professional employees from secondary technical schools, the polytechnic and the university science faculties. Most secondary schools in the country are private and their growth much influenced by strong social demand. This is particularly true for the technical streams, 70.8% of which were private (1983) receiving 2-3 applications for each place. The Littoral region, which has the highest proportion of secondary and technical pupils, is in close proximity to the site of the refinery and other oil sector industries so that one may conclude that the possibility of a job in the modern sector has provided a strong stimulus to the growth of private education in the Cameroon.

The oil industry, in common with other large modern sector enterprises, accepts that the educational system could not, for the most part, provide the various specialists required since they need rigorous practical training. Such practical training is not generally available either at secondary or at higher education levels. In effect, the formal education system as in most African countries has major problems in producing young people with technical certificates. The low output from secondary schools is caused by lack of maths and science teachers and the absence of equipment and facilities for practical work. The higher education system too produces too few Science and Technology graduates and also experiences problems in giving enough practical training. The Polytechnic, an élite establishment as regards resources, comprises only 2% of the total student body. It is from the latter that the

oil industry seeks to recruit its high level technical manpower, in addition to itself funding higher education students both in the Cameroon and abroad.

Despite the difficulties noted above, the formal educational system has been able to respond to needs to some extent since the proportions of employees holding formal educational qualifications of BAC and above increased by 6-10% in the enterprise sample during 1980-86. Nevertheless there are still shortages of experienced engineers, computer operators and R&D staff.

Though the oil industry has adopted the policy that it must arrange for the training of its own manpower itself, the fact that there is no school, department nor option on petroleum studies, has meant that the education system and the industry have few opportunities for direct contact on a regular basis, whereby curricula, practical work, R&D etc. might be discussed.

The system of training devised by the oil industry -- mainly the enterprises' own centres plus the local refinery training centre is impressive. It is flexible in that according to skills needed, in addition to local training centres, staff are sent to other firms in the Cameroon and abroad, and to academic institutions in-country and abroad. The latter opportunities are fewer and are aimed at high level staff. The main training effort is concentrated on the skilled worker category (operations and maintenance). Financial support is generous, covering all aspects of travel, daily allowance, board and lodging etc.

The largest local oil industry training centre is that of the refinery, which was set up in 1981 and does both long (career planning) and short term training, i.e. it gives for example a 7-year course for an "agent de maitrise", trains up management staff through all the different departments over a long period, and gives short courses, particularly on safety which are attended by staff of other firms. The greatest training effort had to be made in 1980/81 to train operators, followed by maintenance and safety training, but five other kinds of personnel were trained from laboratory to senior technical staff and inspectors. However, by 1984 the training needs had become much more complex: 16 types of training were given including for instance computers, law, boiler-making, management. The centre expects an even wider range of training responsibilities as the refinery is extended, gas exploited etc. The refinery has obtained satisfactory results with its training centre: it

has produced efficient skilled workers as needed and filled a considerable number of high level posts with Cameroonians. However, this has been a costly process since such staff still have to be given training abroad. This local training centre is of the opinion that the time has come to widen the scope of its activities to include R&D and higher level training but it does not have the resources to do so.

The sample of employees confirmed the wide extent of training activities organised in the industry -- 68% of employees of producers of crude had received in-service training, and 82% of those in the refinery. However, a lesser proportion 46% of employees in distribution and stocking had been trained in-company. Most of the in-service training is given to skilled workers (67%) but even at higher levels more than half had also received some training but here it was more likely to have been seminars or missions abroad.

The firms were above all practical in their search for and recruitment of staff: skilled level workers were only definitively recruited after training and half the firms visited educational institutions for the recruitment of technicians. Only a quarter used newspaper advertisements or employment agencies and this was for specialised staff like computer operators. Actual recruitment for higher level staff depended on academic performance, and again professional training, plus Cameroon nationality in line with the policy guidelines set down by the Government.

The employees largely confirmed the statements of the enterprises but in one respect surprisingly differed in that by far the greatest proportion came to know about a job possibility in the oil industry through friends and acquaintances -- only 2% mentioned information in educational institutions. Responses to the questionnaire on criteria used all stressed the ability to learn and perform on the job, for which they are well rewarded in comparison to average salary levels in the Cameroon. The salaries of the employees showed rapid increases over a 5-6 year period.

From an analysis of the socio-economic origins of the employees and sources of finance for education it was evident that the oil industry attracts first generation educated and those who have to make their own way by working during formal education. Employers contributed little to formal education (11% of the sample) and when they do it is at M.Sc. or Ph.D. level. However, when asked if they were satisfied with the output

from the formal education system, it was the primary and secondary education levels which received some criticism, i.e. basic maths and technical subjects.

The survey showed that the major forms of co-operation among the three sectors remained bilateral i.e. industry-government and industry-education. Industry-government relations are confined to policy for the exploitation and development of oil, and mainly licensing arrangements.

Industry-education relations are for the most part very limited: the granting of fellowships at higher education level and the meeting of staff in seminars from time to time. The exception to this is the Cameroonian refinery which accepts both higher education and secondary technical students for practical training.

The following implications could be derived for education and training in the country from the above findings:

(i) Cameroon should emphasize basic science and mathematics in its secondary schools, at present the level is unsatisfactory according to our survey of employers and employees of the oil industry;

(ii) The performance of secondary technical schools has to be improved by (a) linking them more closely to industries, (b) making courses more work related; (c) recruiting qualified teaching staff, especially in mathematics and science, with a national incentive system; (d) transferring, if possible, part of the training to the industries;

(iii) The University of Yaoundé should, again in co-operation with the industry and government, strengthen its scientific and technical branches. To start with the university and its branches could open short cycle diploma programmes in technology. This might be done at the university at a cheaper cost than done at the polytechnic at present.

(iv) The result of limited bilateral relationships among the three sectors (government, industry, education) has meant that policy making for the oil sector and for education does not consider changes which might be desirable in the education system as the industry develops. It is evident that the general weakness in technical and professional education can only be overcome in the long term but that does not preclude certain short term measures being taken. For example, as mentioned before, some of the multinationals expressed dissatisfaction with the quality of primary and secondary education but they have up to the present had no direct channels of communication to express precisely what they require,

nor has the educational system at these lower levels been able to benefit from co-operation as has been the case for the refinery i.e. acceptance of students for practical work. The oil enterprises might begin a school "sponsorship" programme in their locality with talks by oil personnel on the industry, provision of films, equipment, etc.

Another aspect that could be dealt with by a mechanism of tripartite co-operation is the qualification structure resulting from the French type educational system which is now being found to be too rigid. Valued workers are obliged to leave in order to obtain further qualifications before they can enter the ranks of the professionals. Recognition of on-the-job training and work as part of higher education in petroleum studies would allow more highly qualified staff to be trained. It would keep them in the enterprises and provide more motivation to all staff to undertake higher education.

Here it should be mentioned that in Korea a governmental agency (Korea Technical Qualifications Testing Agency) was set up in 1976 to standardise the various tests of knowledge and skills gained in industry. It registers the successful examinees as holders of specific diplomas for employment in certain posts. A similar agency in the Cameroon would serve not only the oil industry but the whole of the industrial sector.

In sum, while oil sector training is flexible and practical, the educational system is not and could surely benefit from contacts to bring in new ideas, content, methods etc., even if only first of all in limited areas. Success would thereafter filter into other departments.

While it is true that the oil sector conducts its own training according to its own needs, it is a fact that a considerable amount of expensive training is given and large numbers of modern sector manpower are produced by them. The multinationals, while foreign and private, should be considered as a rich resource for development of *both* the country and manpower and as such, should be treated as participants in deliberations on educational planning at all levels.

(v) In order to help develop local technological capability, the country should take advantage of the infrastructure of SONARA as well as its willingness to start work on research and development in the oil industry. In this area also tripartite co-operation among the university, government and industry is essential.

The above suggestions, we hope, will provide the decision-makers of the country with some hints for formulating educational and training policies for the development of the country's key economic activity -- the oil industry.

Case study No. 6

Local links between education, research and industry in high technologies in France[34]

This study of the electronics industry in France and in particular the development of two technological zones ("technopoles") enquired into the benefits which can be attained from the geographical proximity of higher education, further training, research and industry.

There were four specific objectives:

(1) To present a general overview of the activities of government and the enterprises to promote new technology;

(2) To evaluate the nature of the determinants, forms and results of co-operation between institutions of higher education and research and enterprises in the field of training, recruitment and research;

(3) To identify obstacles which impede the development of relations between these institutions and the means to remove them;

(4) To identify the practical implications of these links for educational management and planning.

The field of electronics was chosen since it requires a high level of initial education (Bac + 5) followed by continual training to keep abreast of the evolution of knowledge. In France, at each stage of technological development, both the state and industry have created institutions (INRIA, CNET) to adapt training to new needs. What was felt to be more problematic in this country was the activation of dynamic research by the cross-fertilisation of ideas between higher education and industry.

Fifteen years ago, most municipalities wanted to set up industrial zones or business parks, today regional councils are debating the advantages of setting up "technopoles". One opinion was that the setting

34. Laudet, M. et al., Paris, IIEP, 1989 (mimeo).

up of a dynamic collective was more important for industrial renewal than the new technologies themselves. Each region is different in resources and must itself devise the appropriate means for expansion.

Eight characteristics of a technopole were enumerated. They cover:

(1) the existence of a number of research laboratories to promote industrial innovations;

(2) opportunities for further high level training;

(3) a system for exchange of information;

(4) industrial groups who are leaders in their field;

(5) services necessary for high technology enterprises;

(6) a voluntary body to promote activities and publicity in the zone;

(7) a body engaged in overseeing the structured organisation of space and infrastructure (airport, roads, telecommunications, housing);

(8) an ethos that is highly receptive to innovation.

The benefits that technopoles might bring differ in extent:

- they can help Europe to catch up with the USA and Japan and reinforce European co-operation;
- they are a means whereby the national industry can combat world competition;
- they are a means of regional development, notably for declining areas.

It is not a structure that has appeared in any number in France; the phenomenon as concerns electronics was of course first seen in "Silicon Valley" USA but similar conglomerations exist in Japan and the U.K.

1. The evolution of technological policy in France

The electronics industry has a long history dating from the telegraph in the 1890s but today only two large firms are competitive internationally (CGE and Thomson-CSF). The weaknesses and strengths of the electronics industry are largely attributable to lack of coherent government policies. The strength of the industry in professional military and space electronics and telecommunications is due to state protection of the market -- the firms are considered as champions of national independence and have been given large contracts over a long period and been assisted with R&D by the setting up of high quality

research institutes. Telecommunications, for example, was equipped with an adequate administrative structure for both industrial production and R&D. It has its own source of financing in the "Caisse nationale des telecommunications" and has not been subject to the vagaries of state policy and the market as regards its risk capital. Today it controls the French market and as a general rule makes use of French suppliers.

In other fields of electronics, government industrial policy has sometimes been contrary to the enterprises' own development strategies; it has been fragmented, inconstant and delayed (for informatics and integrated circuits) or inexistant (for office equipment and industrial components). The fact is that the electronics industry is highly interdependent, one sector depending on innovation in another, e.g. innovation in informatics assists the development of office equipment, micro-informatics and services.

Today, in the midst of the informatics revolution, all sectors of the productive system have to respond to the challenge of rapid technological change. The government has belatedly created ANVAR (*Agence de l'Informatique, le Fonds de la Recherche et de la Technologie*) to assist dissemination of new technology to industry.

In essence any industrial policy needs to cover:

- the assurance of a long term market to firms so that they are willing to take technological risks;
- the establishment of a mechanism to provide risk capital in fields of high technology e.g. a legal statute governing a Financing Association for Innovation;
- means to assist the mastery, accumulation and dissemination of technological knowledge so as to develop centres of excellence able to meet international competition;
- enable the different actors/sectors to communicate and provide a forum for cross-fertilisation of ideas.

2. Technopoles

Technopoles, in theory, would seem to be an ideal vehicle for establishing strong relations between training, research and industry to provide impetus to innovation and the restructuration of national and regional industrial tissue. However they do not as yet form part of industrial policy in France. ZIRST, Meylan, is an autonomous regional

structure and received no aid from the state, though one government training agency (CNET) was established there on the decision of the Directorat Général de Télécommunications, this being due to the fact that the Grenoble region has long been recognised for its expertise in electronics and tradition of research-industry relations. The other technopole, Sophia Antipolis, was a product of land management decisions of the Alpes-Maritime region, which promoted the site in an effort to attract new high tech industry and establish research-industry links.

2. ZIRST, Grenoble

The most active and developed technopole is that at Grenoble. ZIRST has been a centre of research for some decades in areas of energy transfer, hydraulic equipment and metallurgy. At the beginning of the 1960s, the Centre of Nuclear Studies was set up here; at the same time the Polytechnic, the Scientific and Medical University and the National Centre for Scientific Research were expanded. During the same period the local electronics industry underwent rapid growth. In fact, local production of computers originated at the Polytechnic and a Laboratory of Electronics and Information Technology was set up both to carry out R&D and to ensure the flow of technology to industrial sectors.

ZIRST was the result of local initiatives which wished to combine the advantages of local training and research in order to promote development. Take off was slow due to lack of financial assistance from public sources but was favoured by:

- the existence of high level education and research centres interested in industry;
- a local consensus between education and research on the need to establish a technological zone;
- subsequent establishment of large companies on the site having managers of the same educational origins.

The zone was designated for development in 1968 and in 1971 a "PROZIRST" association set out its ideas on management and development. As from 1975, when four firms were set up by engineers who had decided to leave their large employers, new firms began to be established on the site. In 1977 the National Centre of Telecommunications Studies (with 320 employees) moved into the zone.

The survey in 1986 showed that the zone comprised 130 firms, and that 70 per cent of employees were engineers, high level technicians or managers. Two large companies (with head offices elsewhere) constituted one-third of those employed, 49 small service firms employed 14 per cent while the hard core of 80 firms employing 52 per cent were small and specialising in the new electronics technologies. Most products were industrial applications designed for specific clients -- there was little complementarity of effort. On the contrary, firms were rather competitive and not disposed to co-operate. Inter-industry exchange was thus impeded though there was some mobility of employees between firms.

It was found that the majority of linkages in ZIRST were research-industry, the principal vector being the existence of local high quality education. It is the strategy of many of the firms to establish co-operation with higher education institutes by R&D contracts, technological partnerships, or joint exploitation licences. The Polytechnic considers that it has been the creator of about 40 of the firms at ZIRST. The successive output of local colleges and universities forms the cement of the technopole. Engineering employees stated that the principal attraction of ZIRST is its role as intermediary between campus and industry. Graduates retain their links with their university -- 72 per cent of them were recruited directly from the Polytechnic. Relations with other higher education institutions are less strong and links are mainly with the firms working in new technologies. Sixty per cent of the firms had relations with local education, 68 per cent accept students for practical courses, 24 per cent receive graduates to work on their theses and 26 per cent of the firms have employees who teach part time in higher education.

The two large firms were established on the site mainly due to political pressure which was also true for some small firms. However, the 40 created at the site offer complementary services, research and training. Few of the firms are manufacturers but have reinforced research activities and industrial renewal e.g. in the application of robotics and artificial intelligence.

The crucial problem which has to be faced is making the progression from prototype to industrial product. Is the role of a technopole just a seed bed or initiator?

4. Sophia Antipolis, Nice

The survey showed that firms in the zone had no particular reason for locating themselves at Sophia Antipolis. They had been attracted by the prestige attached, the Côte d'Azure and the proximity of Nice airport. Large national and multinational firms predominate. An extension of the Paris Mining School was established here, its objective being to counteract the technological desert of the Maritime Alps. Most firms did not have regular contacts with the school which maintains links through its Graduate Association. However, this concerns top management only. One of the graduates organises a monthly breakfast for cross-fertilisation of ideas.

The Director of the Mining School found difficulties in liaising with local industry since it was not homogeneous.

The National Institute of Research on Informatics and Robotics is also at Sophia Antipolis but does not yet have any contact with the firms on site. A drawback is that half its staff are external consultants.

Nevertheless, the zone has the image of a potential national and international technological centre and its future emphasis will be on high level training, particularly informatics and engineering science. The conclusion drawn was that up to the present, the promoters had devoted more attention to creating an international or inter-regional image than to mobilising local energies for research and training.

Conclusions

Two major conclusions were drawn from the study as a whole:

1. The first concerned the establishment of a system of relationships between research, training and industry. It was concluded that a technopole cannot exist without a training and research element. The only micro-system existing at Sophia Antipolis was that created by the School of Mines. Such relationships always existed at Grenoble and ZIRST was an expression of a desire to establish them in concrete form. However, development of a co-operative micro-system has come up against the obstacle of industrial competition. A "high tech" industry needs to protect the specific technologies which give it an advantage while at the same time it seeks to share in the progress of general technology. This dilemma makes relationships difficult to develop fully. The National Polytechnic of Grenoble (INPG) is able to act as a filter and diffuser of information to some extent, and is also a mediator of research and training. For the polytechnic, ZIRST is an object of prestige, an observation site and source of feedback on industrial needs and future trends in order to make adjustments to teaching and research programmes.
2. The second major conclusion concerns the extent of industrialisation which can be attained by establishing a technopole. Industry in the Grenoble region as a whole has benefitted from ZIRST, which has reinforced the tendency of the region to specialise in new technologies, at least in research, innovation and prototypes. However, no corresponding industrial production or diversification has occurred. Industrial employment in the region has decreased in recent years, the technopole has thus not been able to bring any major advantage in this respect.

Thus technopoles can assist restructuration of the national and regional economy only to a limited extent and only when training, research and industry work together with a reasonable degree of mutual confidence. The overall actual effect of technopoles on regional development is difficult to measure, there being advantages on the R&D side which may have very long term effects. It was observed that it was

the small and medium sized firms which are most attracted to technopoles and are most receptive to new technology -- which reinforces the findings of the study in the Republic of Korea.

A further conclusion, which is important for educational planning and management of infrastructure, is that it seems to be the centres of education and research which attract industry to them and not the other way round.

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IIEP Research Report No. 85

The phenomenon of technological development has assumed great importance in the contemporary world. It is reflected in unprecedented growth in productivity with accompanying labour saving, in improvement of quality of products, in the launching of new products and services, and in the development of new branches of activity. At the same time it is transforming the production process and organisation of work in different sectors of the economy, generating new occupations and calling for new skills and qualifications. Technological development is also transforming the pattern of consumption and the life styles of broad sections of the population all over the world. What role have technological policies of the State and private enterprise played in the development of the key industries of a country? What was the impact of this development on automation of the production process and consequently on the employment and qualifications structure of workers in these industries? How did the education and training system respond? How did the government-industry-education interface help develop the education and training system both in general and for the particular industry? What lessons may be drawn for formulating educational policies which respond to technological development in key industries? Based on surveys of enterprises, employers and institutions of education and training in six countries (Algeria, Cameroon, France, the German Democratic Republic, Indonesia and the Republic of Korea) the present study attempts to respond to the above questions while summarising the findings of the individual case studies published separately.

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